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ASPHALT SURFACE TREATMENTS

FOR

LOCAL ROADS AND STREETS

MANUAL

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ASPHALT SURFACE TREATMENTS FOR LOCAL ROADS AND STREETS

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I. INTRODUCTION TO SURFACE TREATMENTS

Surface Treatments are thin applications of asphalt, with or without aggregate, to an existing pavement surface. There are many types to choose from when selecting a treatment for a specific purpose.

Because of the broad range of materials and methods available, surface treatments satisfy many needs in effective operation of road and street systems. They are major tools for preventive maintenance and also satisfy many corrective maintenance needs. They are widely and effectively used as the initial surfacing over granular bases. They are increasingly used over cracked, existing surfaces to reduce reflection cracking in asphalt overlays.

It is apparent that consideration of surface treatments is an important part of any pavement management program. Their effectiveness is dependent upon selecting the proper treatment, selecting the proper materials for that treatment, good design to provide the proper quantities of asphalt and aggregate, and careful construction to produce the desired result.

Selection of the proper surface treatment to use in a given location depends upon the problem to be corrected. First, can a surface treatment correct the problem? Second, if it can, what type will do the most effective job? Third, are the materials, equipment, and personnel available? Fourth, is the selected surface treatment the most cost effective way to correct the problem? These questions can only be answered with reasonable accuracy by having a rather thorough knowledge and understanding of each type surface treatment, its purpose, and how it is constructed. It is the intent of this manual to provide that knowledge and understanding.

USES OF SURFACE TREATMENTS

Before considering the types of surface treatments, it is desirable to look at what they can and can't do. Once this is understood, a type that satisfies the needs for such construction can be selected. The following discusses major advantages and limitations of surface treatments.

Sealing

Probably the single most important use of surface treatments is to seal a surface and prevent, or retard, the entry of water and air into the underlying pavement structure.

When constructed over an existing asphalt surface, the rate of aging or hardening of asphalt in the surface is decreased, helping the pavement to provide longer service before becoming brittle and cracking under traffic loads. The development of shrinkage cracks may also be prevented or retarded by delaying asphalt hardening.

The treatments prevent entry of water through porous pavements and seal narrow cracks, preventing softening of underlying granular base and subgrade. This can greatly reduce the weakening effect of surface water on the pavement and provide a longer service life. Sealing is a major preventative maintenance operation that, when properly used, can considerably reduce the long term operational cost of road and street pavements.

Improved Surface Properties

While all surface treatments should act as seals, frequently they are applied for other reasons. Generally, these treatments are corrective maintenance operations.

An existing surface may be low in asphalt content or undercompacted and surface particles are being removed by the action of traffic or weather. If this is permitted to continue, potholes will develop as well as a loss of thickness. Asphalt from a surface treatment will cement the surface particles in place and prevent further loss thereby increasing pavement life.

Skid Resistance

Surfaces can become slick and dangerous for several reasons. Surface texture of some surface mixtures can be very dense and become slick. Aggregate particles in the surface can polish and become slick. Excess asphalt in the surface mix may be forced to the surface as traffic compacts the mix. Stripped asphalt within the mix may come to the surface. Loss of cover aggregate in a seal coat may leave an asphalt layer on the surface. Cover aggregate may, if the supporting layer is soft, become so deeply embedded that all texture is lost, leaving an almost solid asphalt surface. All of these conditions reduce the skid resistance to dangerously low levels, are a hazard to the using public, and a potential liability to the road or street agency. Surface treatments, selected to fit the need, can correct each of the described conditions and restore a safe, skid resistant surface.

Improved Visibility

The relatively coarse texture of surface treatments reflects light back to the driver better than very smooth textured surfaces. With a light colored cover stone, such as limestone, visibility, especially on rainy nights, is considerably improved and pavement edges are more easily seen. Generally this is not a primary purpose for surface treatments but, in some cases, improved safety for the user makes it important.

Initial Wearing Surface

Frequently, surface treatments are used as the first pavement surface on a primed granular base. Thicker but very flexible surface treatments should always be selected for such uses. They seal the surface to prevent entry of water and provide the actual wearing surface. They are much too thin to add any structural strength to the pavement, but they help the granular base develop its intended strength by protecting it from surface water and displacement by traffic. It is apparent that this use is intended specifically for roads that have granular bases thick enough to support the using vehicles. On some low traffic roads, repeated applications of surface treatments may provide all the paving that is needed. More often, the surface treatment is first stage paving to be followed after a few years with a hot-or cold-mix surface. This delay permits the correction of any soft spots before more expensive surfacing is constructed.

Prevention of Reflective Cracking

When an existing surface that is badly cracked is resurfaced, those cracks may be extended through the overlay by traffic use. This is reflective cracking. Surface treatments have been used for many years to prevent or retard formation of reflective cracks. It has been rather effective when the existing pavement plus the overlay thickness provide adequate structural strength. When a surface treatment is used for this purpose, the largest size cover aggregate, that is practical to use, gives the best results. Often such surface treatments are constructed as much as a year in advance of overlay construction to let traffic compact them very thoroughly. They also may be effectively constructed as part of the overlay project.

Skin Patching

Surface treatments may be used to seal local areas. Such areas may vary in size from a few square yards to hundreds of square yards. This use is referred to as skin patching and is a part of normal pavement maintenance.

Areas are patched in this manner to correct locally porous sections of surfacing. It could be segregated areas through which surface water is penetrating. It could be an area that cracked because excessive water has entered the base and subgrade. After correction of the water problem, the section may improve in strength. The skin patch seals the area, preventing weakening by surface water entry. In all cases, skin patches are considered temporary corrective maintenance that will delay the need for more expensive treatment.

LIMITATIONS OF SURFACE TREATMENTS

From the previous discussion, it is seen that surface treatments can be effectively used for many purposes. There are also some things that should not be expected and cannot be accomplished.

Structural Strength

All surface treatments are thin, varying from a tiny fraction of an inch to about one inch in thickness. They are much too thin to add structural strength to the pavement. The underlying structure must be thick enough and strong enough to adequately support traffic. If it is, then, and only then, can the surface treatment do its job.

Ride Quality

Most surface treatments will not improve ride quality. They add one stone thickness to the surface and reproduce the surface shape they cover. There are, as will be identified later, a few premixed seals that provide minor leveling. In all cases, good surface profile is best accomplished before the surface treatment is constructed.

Traffic

Surface treatments generally are best suited to low and medium traffic roads. If they use cover aggregate, particles can be dislodged and thrown by traffic. This is most likely to occur on high traffic and high speed roads. Also, because they are thin, service life on high traffic roads is very short.

Life

A surface treatment has a rather short useful life which may, on the average, vary from about 2 years to about 7 years depending upon location and type used. This limitation should be recognized in planning use of future funds.

Weather

Surface treatments should never be constructed in cool or wet weather. Air temperature should be 70 degrees F. or, preferably, above. These very thin layers chill quickly and good construction is almost impossible unless surface and air temperatures are above 70 degrees F.

Rain will remove the asphalt if it hasn't already set up. An excess of water on the surface or in the aggregate prevents asphalt from properly coating the aggregate. Water also rapidly chills the pavement. It is best to construct surface treatments on a clean dry surface with clean dry aggregate. Successful work can be done, however, when both surface and aggregate are slightly damp if the air temperature is well above the minimum. If some fine dust is present in the cover aggregate or existing surface, a damp condition will provide better coating of both aggregate and surface.

As already noted, construction of surface treatments should always be scheduled for hot weather months. If practical, they should be completed 4 to 6 weeks, or more, before the beginning of cool fall weather. This permits curing of the emulsified asphalt under warm conditions. If constructed too late in the season, curing may not be sufficient to prevent winter damage.

II. TYPES OF SURFACE TREATMENTS

Surface treatments may be divided into three classifications that essentially describe the way they are designed and applied. These are asphalt/aggregate applications, premixed applications, and asphalt applications. Within each of these classifications there are several different treatments. Each has one or more specific uses. Table 1 and Figure 1 will identify and describe the applications in each classification and their uses (see pages 10 and 11).

ASPHALT/AGGREGATE APPLICATIONS

These are probably the most broadly used surface treatments. They consist of a layer of asphalt with aggregate cover. The members of this group are single or multiple surface treatments.

Single Surface Treatments

A single surface treatment consists of spraying a predetermined quantity of rapid curing asphalt, usually rapid setting emulsified asphalt, on a prepared surface and covering this layer with a one stone thickness of aggregate. Rolling and sweeping off excess stone completes the construction.

When the aggregate is crushed stone, this application is often called a "chip seal." If pea gravel is used as cover stone, it is usually called "grit seal." When sand is the cover aggregate, it's a "sand seal." While the name may change, all are single surface treatments. They range in thickness from about one eighth inch to as much as one inch. Usually they are within the range of 3/8 inch to 3/4 inch thickness.

These applications are always used on existing pavements. The primary purpose is to seal the surface and/or provide an improved

TABLE I

ASPHALT SURFACE TREATMENTS

Type of Construction	Description & Uses	Typical Asphalts	Construction Hints
SINGLE SURFACE TREATMENTS	Single most important low cost maintenance method. Produces an all-weather surface, renews weathered pavements, improves skid resistance, lane demarcation, seals pavement.	HFRS-2	Stray-applied. Many types of textures available. Key to success: Coordinate construction, use hard bulky grained, clean aggregate, and have properly calibrated spray equipment.
DOUBLE SURFACE TREATMENT	Two applications of binder and aggregate. The second chip application uses a smaller sized stone than the first. Durable, provides some leveling, available in a number of textures.	CRS-2 or RS-2 HFRS-2	See Single Surface Treatment.
GRIT or SAND SEAL	Restores uniform cover. In city street work, improves street sweeping, traffic line visibility. Enriches dry, weathered pavements; reduces raveling.	CRS-1, CRS-2 RS-1, RS-2 HFRS-1 HFRS-2	Spray-applied with sand cover. Roll with pneumatic roller. Avoid excess binder.
SLURRY SEAL	Used in airport and city street maintenance where loose aggregate cannot be tolerated. Seals fills, minor depressions, provides an easy-to-sweep surface. The liquid slurry is machine-applied with a sled-type box containing a rubber-edged strike-off blade.	QS-1, QS-1h, SS-1 SS-1h	Pretest the aggregate and emulsion mix to achieve desired workability, setting rate, and durability. Calibrate equipment prior to starting the project.
HOT PLANTMIX SEAL	A machine laid application of fine hot plantmix to a stable existing surface in a layer of 1/2" to 1" thickness, seals, levels and improves surface properties.	AC-10 AC-20	Use construction methods normal for hot mix asphalt pavement.
COLD PLANTMIX SEAL	A machine laid application of of cold plantmix to a stable existing surface in a layer 1/2" to 1" thickness, seals, levels, and improves surface properties.	MS-2, CMS-2, HFMS-2 AE-60, MS-3, MS-3c	Use construction methods normal to cold plantmix paving. Restrict traffic speed to 25 MPH until complete set of emulsion occurs.
FOG SEAL	A very thin seal of diluted slow setting emulsion sprayed on an existing surface. Seals surface pores, prevents loss of surface aggregates and retards asphalt hardening.	SS-1, SS-1h, CSS-1 CSS-1h	Keep dilution rates high--usually 2 to 3 parts water to 1 part emulsion and application rates low. Make two applications, if necessary, to achieve desired seal.

FIGURE 1 -- TYPES OF SURFACE TREATMENT

A. Asphalt/Aggregate Applications

Single Surface Treatment

3/8" to 1" thickness

One application, each, of asphalt and stone.

Double Surface Treatment

1/2" to 1" thickness

Two applications, each, of asphalt and stone.

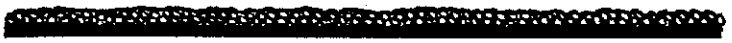
Grit or Sand Seal

1/8" to 3/8" thickness

One application, each, of asphalt and sand or grit.

B. Premix Applications

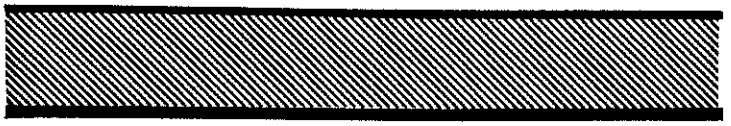
Slurry Seal



1/8" to 1/4" thickness

Premixed, well graded, sand and asphalt.

Hot or Cold Plant Mix Seals



1/2" to 1" thickness

C. Asphalt Application

Fog Seal

very thin

Spray application of asphalt.

riding surface. They can improve skid resistance and visibility effectively. They also can be used as skin patches. They cannot strengthen the pavement or improve the ride quality.

When well designed and constructed, these treatments have an expected effective life of 2 to 5 years. They are most effective on low traffic roads but may be used on pavement having several hundred vehicles per day provided the percentage of trucks is low.

Double Surface Treatments

Double surface treatments differ from the single version in that two applications of asphalt and cover aggregate are made.

The first application of asphalt is usually less than would be used for the same cover stone in a single surface treatment. When construction of the first layer is completed, a second application of asphalt, about half again as much as the first application, is made on the cover stone already placed. This is then covered with stone that is slightly smaller than used in the first stone layer.

These treatments are sometimes called double chip seals. Depending on the stone sizes used, they can vary in thickness from about 1/2 inch to slightly more than 1 inch.

Double surface treatments are used on existing paved surfaces and as initial surface construction for aggregate based low traffic roads. They are slightly thicker and considerably more durable than single surface treatments.

When constructed on paved surfaces, they are more effective in bridging and closing existing cracks, thus providing a better seal. They also are more durable having useful service lives of 3 to 7 years depending on the using traffic volume. These treatments also are more resistant to truck traffic but are not satisfactory when there will be a large volume of heavy trucks.

These treatments also are used as preventative maintenance and for improvement of surface properties of the pavement, corrective maintenance.

When used as initial surfaces on granular bases, the base layer should always be primed and cured before the double surface treatment is applied.

Other Treatments

The single and double surface treatments above are the principal asphalt/aggregate applications. There are, however, other less frequently used approaches.

"Triple surface treatments" have a third asphalt/aggregate layer. Cape Seals have single surface treatment layers constructed with large aggregate and are then filled with a slurry seal. These treatments add little to the double surface treatment and are more expensive. Their use is rarely justified.

Occasionally a "drag seal" is used with the hope that some leveling can be achieved. This is simply a double surface treatment where drag booms are used to redistribute the first aggregate application to fill in low spots. For several reasons, the desired result is rarely achieved. This treatment is not recommended for any use.

PREMIXED SURFACE TREATMENTS

There are three types of premixed seals that may be used. They are slurry seal, hot plantmix seal and cold plantmix seal.

Slurry Seals

Slurry seal material consists of a well graded sand, water, quick set emulsified asphalt and, in some cases, a setting agent. Proportioning of aggregate, water, and asphalt must be very carefully done to provide the desired results. These mixture components are carefully blended in a specially designed truck mounted machine. Mixing and spreading is done by the same machine.

Slurries provide a thin, gritty surface layer that is reasonably effective in resisting wear and in sealing cracks. They also are capable of very minor leveling, but thicknesses greater than twice the maximum particle size are very slow to cure.

Generally, slurry sealing is contracted work. The contractor must be capable of designing the slurry as well as construction.

In humid weather slurry seals may cure slowly. Traffic must not use these surfaces until the asphalt has set, and treated lanes must be closed until set is complete.

Hot Plantmix Seals

Hot-mix seals consist of very fine hot-mix with a maximum particle size of 3/8 inch, or less. If a crushed aggregate is used, they are usually referred to as "asphalt concrete." If natural sands, or blends of natural sand and crushed sand, are used as aggregate, they are often called "hot sand asphalt mixes."

These materials are applied in layers 1/2 inch to 1 inch thickness with the thicker layers being more effective. They are used only over reasonably stable existing pavement. Construction procedures are those normally used for any hot-mix construction.

They are very effective for minor leveling and provide excellent seals and wearing surfaces. They are not very resistant to reflection cracking, and surfaces to be treated must be carefully prepared. If this is done, and the mix properly designed, hot plant-mixed seals should provide 5 to 10 years, or more, service on low traffic roads. Because of its thinness, this seal does not add any significant structural strength but when, over a number of years, several such applications are made, strengthening does occur.

Cold Plantmix Seals

Cold-mix seals require the same well graded fine aggregate used in hot-mix seals except with very little or no dust included. These mixes are made in a cold-mix plant with mixing-grade asphalt emulsions, slow setting or medium setting types. If possible one half or more of the aggregate should be crushed to provide early stability.

These materials also are applied in layers 1/2 to 1 inch thick. They do not develop full strength until they have been in use several weeks or months. Time required to fully cure is dependent upon temperature and humidity. They are used only over rather stable existing surfaces.

As with the hot-mix seal, these materials can provide minor leveling, and provide a suitable wearing surface but do not add significant structural strength. They are slightly porous and

may not entirely seal the surface. When properly designed and constructed, these seals usually have slightly shorter service lives than hot-mix seals, in the order of 3 to 7 years on low traffic roads.

ASPHALT SEALS

This group of surface treatments involves application of asphalt to an existing surface without use of cover aggregate. Included are fog seals, prime coats, tack coats, road oiling and dust palliatives. Only the first, fog seal, is actually a surface treatment but, due to some similarity in materials and applications, all will be identified.

Fog Seal

A fog seal is an application of slow setting asphalt emulsion, diluted with one to four parts water, to an existing paved surface. It is intended to apply a very thin layer of asphalt that is fluid enough to penetrate into the surface pores. Its purpose is principally to seal these pores to prevent water from entering the pavement. It also serves to retard aging of asphalt in the mix.

This application is used when a surface is rather badly oxidized and/or tends to be porous because of mix design or too little compaction. Either of these conditions can cause loss of surface particles under traffic action. The diluted emulsion, usually SS-1h or CSS-1h, is simply sprayed on the surface and allowed to cure.

It is a very low-cost method of preventing or retarding surface deterioration. The user must, however, always remember that a slick surface will result if the quantity applied is excessive.

Prime Coat

A prime coat is applied only to a prepared granular base. It is intended to cement together the upper layer of aggregate, to partially seal the surface, and to develop adhesion between the granular base and the surface to be constructed on it. If a prime coat is not used for this purpose the full strength of the surface and base cannot be developed. Conversely, if it is used, the surface and base can develop their full strength and provide better performance.

In Kentucky, the prime material is almost universally Light Immiscible Cutback Primer. Medium curing cutbacks, grades MC-70 or MC-250, are widely used for this purpose in other areas. The asphalt is simply sprayed on the prepared granular base and allowed to soak into the surface. The application rate can vary from about 0.2 to 0.5 gallons per square yard depending on the density of the surface.

All prime should soak into the surface within 24 hours. If it does not, a light sand blotter must be applied to protect traffic.

Prime coats on granular base are necessary and should always be used. They are rather messy in that traffic will pick up the asphalt and some aggregate before the prime soaks in and cures. Careful signing and traffic control is essential.

Tack Coat

A tack coat is a very thin application of slow setting asphalt emulsion (SS-1h or CSS-1h), diluted with an equal part of water, applied to an existing surface that is to be resurfaced. Its primary purpose is to provide a thin layer of asphalt on that surface so the resurfacing will stick to the existing pavement.

Every layer of an asphalt pavement must be firmly attached to other layers either above or below. The tack coat is the glue that attaches them. If the tack coat is not used, the layers may separate due to bending under traffic loads. If separation occurs, the service life may be reduced by one half or more. In severe cases, slippage failures can develop very quickly and require almost immediate patching. Tack coats are low in cost but can greatly increase pavement life.

Road Oiling

Road oiling is the application of liquid asphalt, usually MC-70, to earth surfaced roads. The oil is sprayed onto the surface in rather heavy applications and allowed to soak into the soil. Repeat treatments are usually required twice each year. This treatment is quite expensive because of the large quantities of oil needed. It has rarely been used in Kentucky. Generally it is not an effective use of funds.

Dust Palliatives

Dust palliatives are sometimes needed on earth and aggregate surfaces. These are light applications of MC-70, Light Immiscible Primer or diluted slow setting emulsion (SS-1h or CSS-1h). Usually the application rate is 0.1 to 0.2 gallons per square yard. These treatments have a very short life and usually must be repeated several times each year. Road surfaces should rarely be maintained in this manner for long periods.

III. MATERIALS FOR SURFACE TREATMENTS

Materials used for surface treatments include a rather broad range of both aggregates and asphalts. The user may have a choice of several different materials that could be used for a single type of treatment. Success of the work often depends upon selecting the proper aggregate and asphalt to meet the needs of a particular use. The following will identify aggregates and asphalts that generally are available and indicate their uses.

AGGREGATE FOR SURFACE TREATMENTS

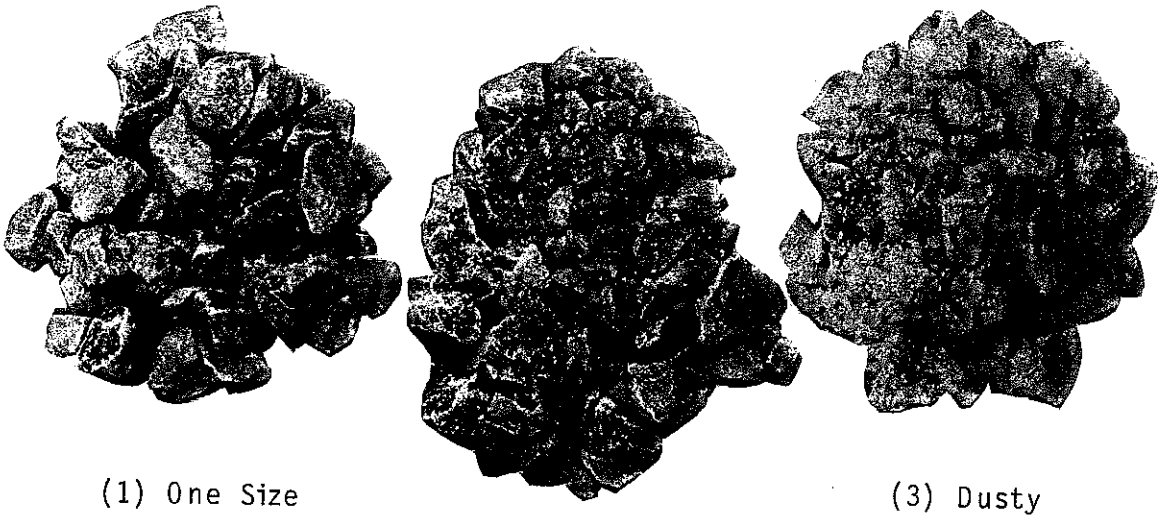
In Kentucky, the most common aggregate will be crushed limestone. In many areas crushed slag, crushed gravel or crushed sandstone may also be available. Both crushed sand and natural sand can be obtained in most areas. These materials are available in many standard sizes and can often be obtained at predetermined prices through the Kentucky Department of Highways (DOT) Price Contract procedure.

Clean, high quality stone is essential to good work. Usually both Kentucky DOH and the supplier can provide data on gradation and stone properties. Since most local agencies will not have extensive testing facilities, the supplier should certify that the material complies with Kentucky DOH specification requirements.

Clean stone has two meanings when applied to asphalt/aggregate surface treatments. First, it means that very little, or preferably no, dust is in the stone. Further, that very little material is finer than the smallest size included in the specification, usually either the No. 8 or No. 4 sieve. Second, it means there is no dust coating on the stone particles.

Sometimes when stone has been stockpiled for long periods, rainwater carries clay and silt dust down into the pile and leaves a coating on the coarse particles. Such a coating prevents asphalt from wetting the stone surface and makes the aggregate unsuitable for use without washing.

FIGURE 2 -- Aggregate for surface treatments, (1) One size, cubical, aggregates will consistantly provide the best treatments, (2) Graded aggregates with some fines, no dust, are more difficult but can be used effectively, (3) Dusty or dust coated aggregates are unsatisfactory.



(1) One Size (2) Graded (3) Dusty

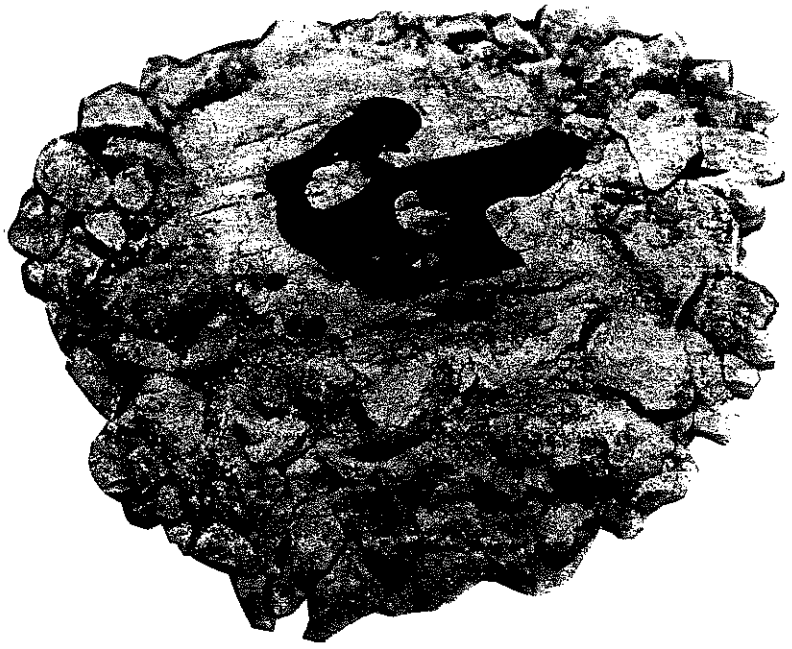


FIGURE 2a --Dust in aggregate causes emulsified asphalt to ball up instead of coating the coarse aggregate particles. Dust coats the balled emulsion and makes coating of coarse aggregate difficult or impossible resulting in loss of cover stone.

Stone Size

A one size stone is best for asphalt/aggregate surface treatments. Production of such stone is difficult, and rarely available in Kentucky. Many standard size stones, identifiable by number, are available. Each has some size range. For example, a No. 8 stone has a maximum particle size of 1/2 inch and a nominal size range of 3/8 inch to No. 8. As much as 15 percent may be 3/8 to 1/2 inch and as much as 10 percent may be smaller than No. 8 but at least 75 percent of the aggregate is between the 3/8 and No. 8, sieve sizes. This is usually referred to as a short graded stone and is about as close to a one size stone as is practical to make. Standard stone sizes are listed in Table 2 (see page 22) and in Appendix B. Those sizes that are generally useful in surface treatments are identified.

Aggregate for Single Surface Treatments

Single surface treatments can be constructed with No. 6, No. 7, No. 8 and No. 9M stone. Occasionally a No. 57 stone may be used but most contain too much intermediate and fine material to be used effectively. Stone with numbers containing two or more digits, such as No. 57, No. 67, or No. 68, all have the same problem, too much intermediate and fine material. Whenever possible select a stone size with a single digit designation.

Selection of the size to use depends on the thickness desired in the treatment. No. 6 stone will provide a surface treatment that is about 3/4 inch thick; No. 7, about 1/2 inch thick; No. 8 or No 9M, about 3/8 inch thick. If No. 57 is used, thickness will be about 1 inch.

In Kentucky, at this time, No. 6 and No. 7 sizes are not always available. They are better for bridging cracks because of their

TABLE II

STANDARD SIZE AGGREGATES FOR SURFACE TREATMENTS

Size No.	Nominal Size (Sieves with Square Openings	Amounts Finer Than Each Laboratory Sieve (Square Openings), Weight Percent								
		1-1/2 in.	1 in.	3/4 in.	1/2 in.	3/8 in.	No. 4	No. 8	No. 16	No. 50
5	1 to 1/2 in.	100	90 to 100	20 to 55	0 to 10	0 to 5	--	--	--	--
57	1 in. to No. 4	100	95 to 100	--	25 to 60	--	0 to 10	0 to 5	--	--
6	3/4 to 3/8 in.	--	100	90 to 100	20 to 55	0 to 15	0 to 5	--	--	--
67	3/4 in. to No. 4	--	100	90 to 100	--	20 to 55	0 to 10	0 to 5	--	--
68	3/4 in. to No. 8	--	100	90 to 100	--	30 to 65	5 to 25	0 to 10	0 to 5	--
7	1/2 in. to No. 4	--	--	100	90 to 100	40 to 70	0 to 15	0 to 5	--	--
78	1/2 in. to No. 8	--	--	100	90 to 100	40 to 75	5 to 25	0 to 10	0 to 5	--
8	3/8 in. to No. 8	--	--	--	100	85 to 100	10 to 30	0 to 10	0 to 5	--
9M*	3/8 in. to No. 4	--	--	--	100	75 to 100	0 to 25	0 to 5	--	--

* Kentucky Department of Highways

large size. No. 6 produces a very coarse surface texture that may be objectionable to some users. No. 7 produces a good, coarse surface texture that is usually quite acceptable. No. 8 and No. 9M both produce rather fine, uniform surface textures and are most widely used because of their availability. No. 9M usually has fewer fines and generally is preferred for these thin treatments. When No. 57 is used, the surface is extremely coarse and rough.

Aggregate for Double Surface Treatments

Double surface treatments are constructed with two sizes of stone. The first stone application should be No. 5, No. 6, No. 7 or, in some cases, No. 57. While No. 57 is not really desirable for this because of its size distribution, it can be used more effectively than in single layer treatments. The second aggregate layer consists of stone one or two sizes smaller than stone used in the first layer. These sizes are No. 7, No. 8 and No. 9M.

If a triple surface treatment is constructed the first application is No. 5 or No. 6 size, the second application No. 7 with both No. 5 and 6, and the third application is No. 8 or No. 9M. As noted earlier, this treatment is rarely suitable.

Aggregate for Grit Seals

This aggregate is sometimes identified as pea gravel but more frequently it meets the gradation for No. 8 gravel. This material, when uncrushed, is not specified by the Kentucky DOH and should only be used if justified by local experience. If crushed, as required by Kentucky DOH, the material is acceptable for general use.

AGGREGATE FOR PREMIX SEALS

Slurry Seals

Aggregate should conform to requirements set forth in Kentucky DOH Standard Specification, Section 410, Slurry Seal. Different aggregate requirements are sometimes proposed by slurry seal contractors. These may be considered provided they have well established records of successful use.

Hot Plantmix Seals

This aggregate should conform to the aggregate requirements set forth in Kentucky DOH Standard Specifications, Section 404, for Bituminous Concrete Surface with all aggregate passing a 3/8 inch sieve. Type II gradation is generally preferred for sand asphalt. Other gradations, having a maximum particle size of 3/8 or 1/4 inch, may be used provided they meet the mixture design criteria stated in the noted specification. Aggregate should consist of at least 50 percent crushed material. Aggregate may be crushed limestone, crushed gravel, crushed slag, crushed sandstone, and natural sand. When crushed limestone is used, 33 to 50 percent natural sand should be required in the aggregate to provide a reasonably skid resistant surface.

Cold Plantmix Seals

This aggregate should conform to the gradation requirements of Kentucky DOH Standard Specifications, Section 404, as noted for hot mix with some modification. The percentage of aggregate passing a No. 200 sieve should be changed to permit only 0-3 percent fine dust in the mix. Other aggregate requirements are the same noted for hot plantmix seals.

ASPHALT FOR SURFACE TREATMENTS

Many types of asphalt are used for surface treatments. The following will identify these materials and where they are used.

Occasionally, rapid curing cutback asphalt may be used or, with special equipment, an asphalt cement. In Kentucky, almost all surface treatments, except primes and hot plantmix, will be done with asphalt emulsions.

For single and double surface treatments, a number of rapid setting emulsified asphalts are available. Fog seals and tack coats are made with slow setting emulsified asphalts diluted with water. Prime coats in Kentucky are usually made with light immiscible primer which is a type of emulsion. Priming also may be done with medium curing cutbacks MC-70 or MC-250. Dust palliatives are made with SS-1h, CSS-1h, Light Immiscible Primer, or MC-70.

All asphalts used should be certified by the supplier to comply with Kentucky DOH specifications for the particular type and grade used. The following will discuss the types and grades that may be used for surface treatments. Appendix B summarizes these asphalts and their uses.

Asphalt Emulsions

Asphalt emulsions are manufactured from asphalt cement, water, emulsifying agents, and in some cases, solvents. The manufacturing process separates the asphalt cement into very tiny droplets and suspends these droplets in water. The emulsifying agents help break down the asphalt and keep it in suspension. Many such agents are available and are selected to provide the properties specified for a particular type and grade.

Stabilizers are used to help control the rate of breaking. Solvents, when used, improve the ability of the emulsion to wet the aggregate. These asphalt-in-water emulsions contain from about 60 to 70 percent asphalt depending on the type and grade. Figure 3 shows such an emulsion. The prime, Light Immiscible Primer, is a different type emulsion. In this case, a small amount of water is dispersed in a cutback asphalt to increase its fluidity.

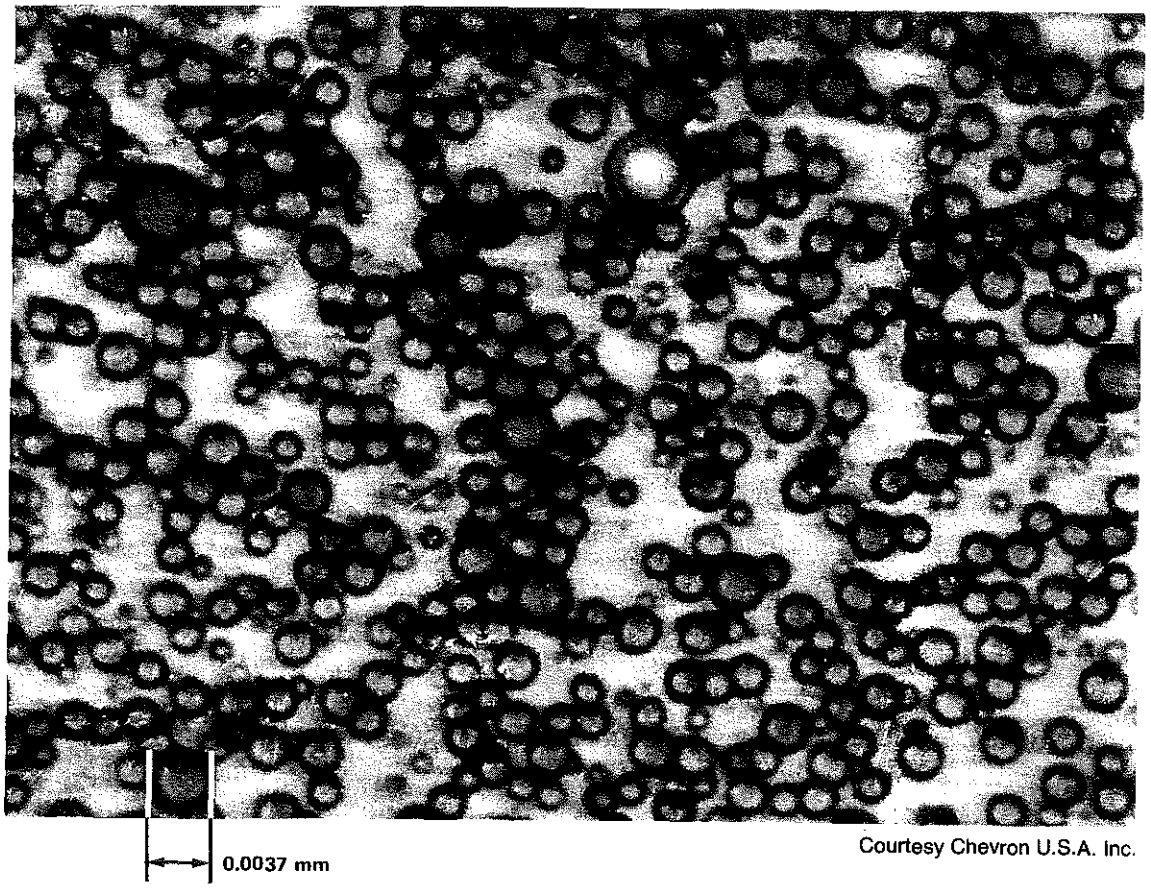


FIGURE 3 -- RELATIVE SIZES AND DISTRIBUTION OF ASPHALT PARTICLES IN AN EMULSION

Emulsified asphalts (asphalt-in-water) are divided into two large groups, anionic and cationic. Anionic emulsion particles carry a negative surface charge and are effective in coating most aggregate. They are specifically intended for, but not limited to, use with such materials as limestone. High float emulsions are included in this group. Cationic emulsions carry a positive particle charge and are specifically intended for such siliceous materials as natural sands and gravels. They will also coat most limestone very effectively. From a use point of view, cationic emulsions may coat aggregate and break a little quicker but either type can be effectively used with most aggregate.

It is always worthwhile to consult the emulsion supplier when work is planned. They can determine whether their particular emulsion will function with the aggregate and treatment you intend to use. If it does not, usually they can make slight changes to correct the problem or recommend another emulsion that will do the job.

For both anionic and cationic emulsions, there are rapid setting, medium setting, and slow setting grades. The anionic grades for surface treatment specified by Kentucky DOH are RS-2, MS-3, SS-1, and SS-1h. The cationic grades are RS-2c (CRS-2), MS-3c, CSS-1, and CSS-1h. In addition, a medium setting high float emulsion, also anionic, is specified: AE-60. A second high float emulsion, HFRS-2, is available for single or double surface treatments. Quick Set emulsions, used in slurry seals, may be anionic or cationic.

Rapid Setting Emulsified Asphalt

Rapid setting grades RS-2, RS-2c (CRS-2), and HFRS-2 are used for single and double surface treatments. They usually can be applied in the required quantity with little runoff. These emulsions break very quickly when sprayed on a pavement surface. Break means that the asphalt droplets separate from the water and join together to form an asphalt film that coats the pavement and cover aggregates. Good coating of the aggregate can only occur if the aggregate is spread on the emulsion before it breaks. The user can see when the break starts since the sprayed surface will turn from brown to black. Usually this takes from one to five minutes.

Medium Setting Emulsified Asphalt

Medium setting emulsions MS-3, MS-3c and AE60 are used only for cold plantmix seal. These materials break at a slower rate which provides enough time to mix, transport, and spread the mixture on the road. They are called mixing grades of emulsion.

Slow Setting Emulsified Asphalt

Slow setting emulsions SS-1, SS-1h, CSS-1, CSS-1h and AE-200 may be used with cold plantmix seal when the aggregate contains considerable dust. They wet the aggregate very effectively but break very slowly requiring the treated lanes to be closed to traffic for longer periods.

All the SS grades may be used for fog seal and tack coat. SS-1h or CSS-1h contains a harder asphalt and are better for this purpose. Tack coats and fog seals are done with the emulsion diluted with water. Use only water that is acceptable for drinking and always add the water to the emulsion when diluting for these uses. These also are mixing grade emulsions although not used for that purpose in some surface treatment work.

Polymer Modified Emulsions

A new group of rapid setting emulsified asphalts has been added in recent years. These are modified emulsions made with rubber or elastomeric polymers added to the asphalt before, or as, it is emulsified. The polymer additives are the more recent and show potential for providing improved materials. They usually contain 3 to 10 percent polybutadiane, polystyrene or other block polymer. Kentucky DOH specifies three of these emulsions in "Special Note for Polymer-Asphalt Emulsions for Seal Coat Applications." They are identified as RS-2S and AE-90S.

The polymer additions do not affect application of these emulsions but do tend to change the way they function in asphalt/aggregate surface treatments. They seem to (1) wet the aggregate better and reduce loss of cover stone, (2) improve traffic resistance, (3) be less likely to crack when cold, (4) be less likely to flush when hot, and (5) be less likely to develop reflection cracking. Because of limited experience with these polymer asphalts, the apparent advantages noted may not always apply. They are sufficient, however, to encourage giving these asphalts a try and determining whether they provide improved service for you.

There is one certain disadvantage in using polymer asphalts. They cost more, about 1.5 to 2.0 times as much. Asphalt cost is about one-third the cost of a surface treatment. Thus, the total cost will probably increase by about 15 to 35 percent when polymer asphalts are used. If they extend service life by these percentages, or more, they are a good buy.

Specifications for Standard emulsions and for polymer modified emulsions are contained in Appendix B. Table III summarizes general usage of Emulsified Asphalts.

TABLE III GENERAL USES OF EMULSIFIED ASPHALT

NOTE—Only those grades of emulsified asphalt in general use have been indicated herein. It is possible that under certain variations of aggregates, or climatic conditions, or both, additional selections might be appropriate. Where the use of emulsified asphalt for applications other than those listed in the table are contemplated, the emulsion supplier should be consulted.

Type of Construction	ASTM D977 AASHTO M 208								ASTM D2397 AASHTO M 140					
	RS-1	RS-2	MS-1, HFMS-1	MS-2, HFMS-2	MS-2h, HFMS-2h	HFMS-2s	SS-1	SS-1h	CRS-1	CRS-2	CMS-2	CMS-2h	CSS-1	CSS-1h
Asphalt-aggregate mixtures:														
For pavement bases and surfaces:														
Plant mix (hot)	...	...	...	...	X[A]	...	...	...	...	...	...	...	...	...
Plant mix (cold)														
Open-graded aggregate	...	...	...	X	X	...	...	...	...	...	X	X	...	...
Dense-graded aggregate	...	...	...	...	...	X	X	X	...	...	...	...	X	X
Sand	...	...	...	...	...	X	X	X	...	...	...	...	X	X
Mixed-in-place:														
Open-graded aggregate	...	...	...	X	X	...	...	...	...	...	X	X	...	...
Dense-graded aggregate	...	...	...	...	...	X	X	X	...	...	...	...	X	X
Sand	...	...	...	...	...	X	X	X	...	...	...	...	X	X
Sandy soil	...	...	...	...	...	X	X	X	...	...	...	...	X	X
Slurry seal	...	...	...	...	...	X	X	X	...	...	...	...	X	X
Asphalt-aggregate applications:														
Treatments and seals:														
Single surface treatment (Chip Seal)	X	X	...	...	...	...	...	...	X	X	...	...	...	...
Multiple surface treatment	X	X	...	...	...	...	...	...	X	X	...	...	...	...
Sand seal	X	X	X	...	...	...	...	...	X	X	...	...	...	...
Asphalt applications:														
Fog seal	...	...	X[B]	...	...	...	X[C]	X[C]	...	...	...	...	X[C]	X[C]
Prime coat-penetrable surface	...	...	...	X[D]	...	...	X[D]	X[D]	...	...	...	...	X[D]	X[D]
Tack coat	...	...	X[B]	...	...	...	X[C]	X[C]	...	...	...	...	X[C]	X[C]
Dust binder	...	...	...	...	...	...	X[C]	X[C]	...	...	...	...	X[C]	X[C]
Mulch treatment	...	...	...	...	...	...	X[C]	X[C]	...	...	...	...	X[C]	X[C]
Crack filler	...	...	...	...	...	...	X	X	...	...	...	...	X	X
Maintenance mix:														
Immediate use	...	...	...	...	...	X	X	X	...	...	...	...	X	X

[A] Grades of emulsion other than FHMS-2h may be used where experience has shown that they give satisfactory performance.
[B] Diluted with water by the manufacturer.
[C] Diluted with water.
[D] Mixed-in prime only.

Courtesy The Asphalt Institute

Emulsion Breaking, Setting, and Curing

Breaking of emulsions has been described as separation of asphalt from the water. When this process is complete and the asphalt has been deposited on the surfaces, water must be removed before the asphalt sets firmly to the surface. Some water is lost by being absorbed into the aggregate or underlying surface. Most of the water is lost by evaporating into the air. When most water is gone, the set is considered complete and the pavement ready for traffic. Complete curing will occur when the tiny quantity of remaining water is lost. This will take weeks or possibly months and is a major reason why construction using emulsions should be done long before cold weather starts.

The user must always be aware that any emulsion treatment can be ruined if rainfall occurs before the emulsion breaks and can be damaged until the set is complete. It also must be remembered that high humidity will slow the rate of water evaporation and thus delay both the break and set of emulsions. This problem can be more severe with slow setting and medium setting emulsions than with rapid setting emulsions. It also is more severe with anionic emulsions than with cationic emulsions.

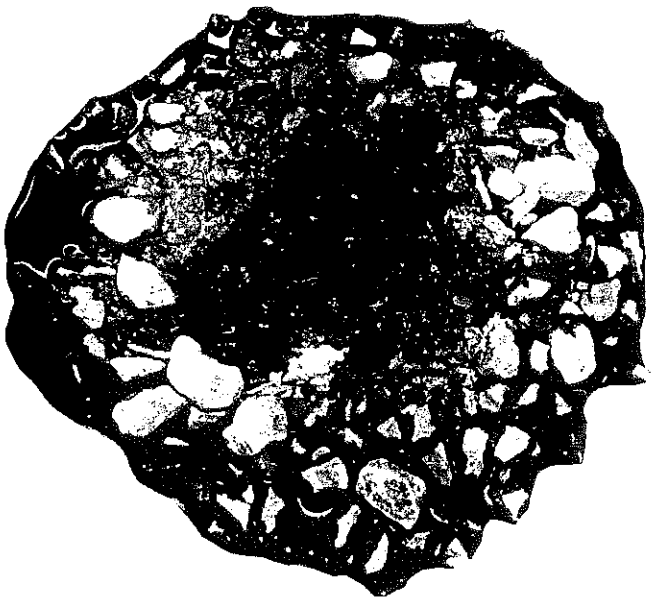


FIGURE 4:

Excessive water in aggregate, or rain before the Emulsified Asphalt sets, will severely damage or ruin the surface treatment. Water dilutes the emulsion and increases its volume and fluidity. Often results in runoff of emulsion and loss of cover aggregate.

Storage and Handling

In any project, it is best to obtain the needed emulsion from a single production batch. When possible, do not store emulsion. Transfer it directly from the delivery vehicle to the distributor or plant supply tank for immediate use. Handling tends to change viscosity, usually increasing fluidity. This does not make the emulsion unusable or even less effective in most cases. It may, however, change the spraying and mixing properties. It also may reduce the quantity that a sloping surface will retain without runoff.

While immediate use is preferred, this is not practical in many cases and local storage becomes necessary. When this is the case, certain precautions in storing and handling are necessary. The Asphalt Institute has provided an excellent summary of Do's and Don'ts that describe good practice in storing and handling emulsified asphalts. Their summary is included as Appendix D.

Your emulsion supplier also should be consulted about your storage facilities and handling methods. He can advise you about safe and effective storage and handling of the particular emulsions he supplies.

IV. DESIGN OF SURFACE TREATMENTS

The design of surface treatments determines the type and quantities of asphalt and aggregate, if any, that should be used to provide the desired result. Design methods for determining needed quantities vary from detailed laboratory procedures to experience and judgement. Asphalt/aggregates applications are designed by both approaches. Premixed applications require laboratory design. Liquid asphalt applications are designed almost entirely on an experience and judgement basis. Regardless of the type or method used, it is intended to provide the quantities of materials that will produce good service on the particular road treated.

DESIGN OF ASPHALT/AGGREGATE APPLICATIONS, SINGLE AND DOUBLE SURFACE TREATMENTS

Design of these surface treatments determines the aggregate, or aggregates, to be used, the asphalt to be used, and the quantity of each needed per square yard of area to be treated.

Selecting Type of Treatment

First, the user must determine whether a single or double surface treatment will give the best results at the specific location. This decision should be based on the purpose of the treatment, the type and condition of the existing surface and materials that are available.

Selection of Aggregate

Second, the available aggregates must be evaluated to determine which size, or sizes, best fits the selected treatment. Then the

aggregate must be checked to assure that particle shape is chunky (cubical) and not flat and elongated, that there is no coating on the particles, and that there is not an excess of fines (supplier should furnish gradation). On the basis of this evaluation, specific aggregates are selected for the work and are the basis for designing the surface treatment. Figure 5 illustrates effect of poor particle shape and size distribution. Figure 6 shows the effect of excess fines and dust in the aggregate.

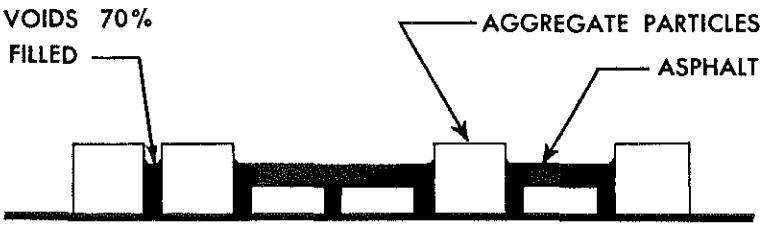


FIGURE 5 -- FLAT PARTICLES ARE COVERED WHEN ENOUGH ASPHALT IS USED TO HOLD CUBICAL PARTICLES

FIGURE 6 -- EFFECT OF EXCESS FINES AND DUST IN AGGREGATE

Note: When fine aggregate or dust reaches the emulsion before the coarse particles it prevents proper coating and embedment of the coarse particles. This causes loss of aggregate, shortens service life, and can cause fat spots.

Selection of Asphalt Emulsion

Third, the type and grade of emulsified asphalt that will best fit the selected aggregate and treatment must be selected. For this type treatment, RS-2, CRS-2, HFRS-2, RS-2S, CRS-2S or AE-90S could be used. More than one suitable type and grade is often available. Usually it is worthwhile to furnish the emulsion suppliers with samples of the selected aggregates. He can then determine the compatibility of available emulsions and offer recommendations on which emulsions function best with the selected aggregates. This provides a better basis for the user's decision on which emulsion to use.

Determine Application Rates

The fourth step in the design procedure is determination of application rates, pounds of aggregate and gallons of asphalt per square yard to be treated. Single and double surface treatments will be discussed separately in the following. There are two general approaches to design. The first is a rather detailed procedure based on the specific properties of aggregate selected for use. The second consists of tabulations which contain the general ranges of application rates with regard to the appropriate sizes used. These tabulated values are based both on results obtained from the first approach and upon experience and judgement. Both approaches use adjustment factors to correct for surface condition, traffic, and excess fines in the aggregate.

Neither design approach will provide precise results. The first approach may supply more exact information but both require careful observation when construction is started to permit adjustment of application rates if needed. It is believed that design based on tabulated values can serve adequately for low to

medium traffic roads provided the user has a reasonable understanding of the factors that affect design quantities. For this reason the factors affecting design will be discussed but the complete details of the procedure will not be included here.

Aggregate Considerations

Most aggregate will not be single size material but will range from some maximum size to dust. Although the percentage that is finer than the No. 4 or No. 8 sizes is small, it can affect both the quantity of stone chips needed and the amount of asphalt required. For this reason the design must be adjusted for gradation.

In the tabulated quantities for design, Tables IV and V, both aggregate and asphalt application rates show a range of pounds or gallons per square yard. These ranges are intended to cover the variations in quantities that result from gradation. If the aggregate is near the center grading for that size stone, both aggregate and asphalt application rates are near the average value. If there are no fines in the stone, application rates will be near the maximum for asphalt and near the minimum for aggregate. If the fines are near the maximum permissible for the size stone, the asphalt application rate will be near the minimum and aggregate rate near the maximum. These general approaches may be used when working with unfamiliar aggregate. When considerable experience has been accumulated with aggregate of a certain size from a given source, adjustment within the ranges tabulated can be made more readily.

Asphalt Considerations

The effect of aggregate gradation on asphalt requirement has been noted. The tabulated quantities are based upon low absorption by a dense existing surface, moderate absorption by the aggregate and low to medium traffic.

Coating and Embedment. Under the above conditions the tabulated asphalt quantity should provide for embedding about 70 to 80 percent of the aggregate height in the emulsion when thoroughly compacted. Remember that 30 to 40 percent of emulsified asphalts is water which will evaporate. It is intended to wet the aggregate with emulsion to the depth stated. When the emulsion cures (loses its water) the aggregate will be coated with asphalt nearly to the surface, but the major quantity of asphalt will be well below the surface as illustrated in Figures 7 and 8.

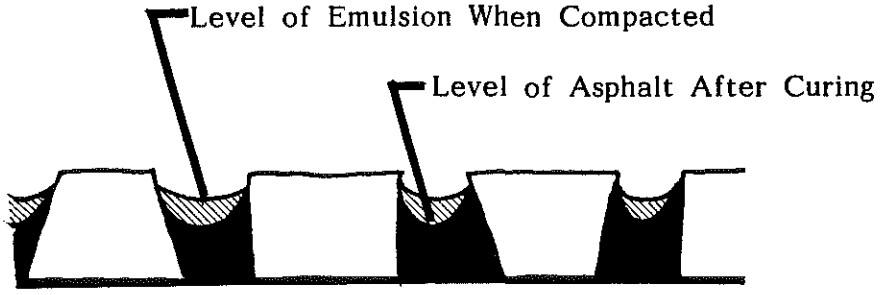
FIGURE 7 -- PROPER EMBEDMENT OF COVER AGGREGATE

a. Loose aggregate before rolling has about 30% voids.

b. Compacted aggregate after rolling has about 20% voids, approximately 70% filled with asphalt.

Note: Aggregate when spread is not properly embedded in asphalt. After rolling it is compacted into a dense single layer properly embedded in asphalt.

FIGURE 8 -- HOW EMULSIFIED ASPHALT FUNCTIONS IN SURFACE TREATMENTS



Note: Asphalt emulsion loses 30% to 40% of its volume when cured. This is water loss. The aggregate remains coated to the depth reached by the emulsion.

Absorption. The existing surface condition may indicate either an increase or decrease in the rate of application needed to achieve the needed embedment. A dry, porous surface will absorb asphalt and the application rate must be increased from 0.01 to 0.09 gal per square yard, depending principally on porosity of the old surface. This is a judgement estimate that should be made and, if necessary, corrected after construction starts.

Certain aggregate also may be unusually absorptive. If it is, a correction similar to that for surface must be estimated. Slag and sandstone usually have high absorption. Some limestone and gravel may also be in this group. Cracks in the existing surface absorb asphalt rapidly. This loss cannot be corrected by increasing the application rate.

Excess Asphalt on Surface. Existing pavements may have asphalt on the surface. In such cases the rate of asphalt application must be reduced. It must be enough to hold the cover aggregate and still leave space for the existing surface asphalt to enter as the cover stone is forced downward by traffic action. This reduction may vary from as little as 0.01 to as much as 0.09 gallon per square yard.

Traffic Effect. In some cases it is necessary to adjust the asphalt rate of application because of traffic volume and/or weight. This is generally unnecessary on low to medium traffic roads. It becomes necessary on roads with high traffic use. Traffic compacts the surface treatment, increases its density, and reduces the void space available to hold asphalt. If the density becomes too great, the surface will become slick and dangerous. For this reason the asphalt application rate on high traffic roads must be reduced. If the high volume of traffic is almost all from light vehicles, the tabulated asphalt application rates should be reduced about 12 percent. When considerable truck traffic is included, asphalt application rate should be reduced about 20 percent.

Quantity Tables

The tabulations referred to above, Tables IV and V, are located at the end of the Design Section, pages 46, 47, and 48. It is believed that their use, with due regard to the considerations just discussed, will result in satisfactory surface treatments. Further, that as local experience develops, needed adjustments to application rates can be made more effectively.

Single Surface Treatments

Design application rates for single surface treatments are contained in the referred-to tabulation. Quantities of asphalt and aggregate are provided for seven aggregate sizes. These are Nos. 57, 6, 7, 8, 9, 9M, and sand.

No. 57 size should be considered only for special purposes and will provide a thickness of about 1 inch. The large quantity of asphalt needed requires that a very high viscosity emulsion be used to avoid excessive runoff.

No. 6 size will provide a very coarse textured surface that bridges cracks very well. Although the coarseness of this surface may be objectionable to some users, it may be needed in areas where truck traffic is heavy. It also is effective when used in preparation of badly cracked asphalt pavement for resurfacing. It is the preferred size when preparing concrete pavement, that has not been cracked and seated, for overlay construction. When used for this purpose, bridging is sufficient to reduce, but not eliminate, reflection cracking at joints. Thickness of these treatments will be about 3/4 inch.

No. 7 size provides an excellent, medium textured surface. It provides a surface about 1/2 inch thick and is reasonably resistant to reflection cracking although not as effective as No. 6 stone.

No. 8 size provides a rather fine textured, uniform surface that is about 3/8 inch. It will bridge only minor cracks and some reflection cracks should be expected. It is used for sealing and renewing surface texture on relatively smooth pavements that have fully adequate structural strength.

No. 9M size provides the same thickness as No. 8 size. It is the most nearly one size stone generally available in Kentucky and functions well in surface treatments.

No. 9 size is really a coarse sand gradation. It provides a thickness of about 1/4 inch. Some fine gravels used in grit seal conform to this gradation. This size material is not generally used in Kentucky and rarely is available in crushed stone. Surface treatments constructed with this size should only be considered for very low traffic locations.

Sand size used for sand seals is either No. 9, as above, or concrete sand. These are very thin, about 1/8 inch, and have a short life even on low traffic roads. They are useful, primarily, to seal porous pavements when virtually no buildup is desired. They also can be considered for improving skid resistance of pavements that have polished aggregate at the surface. They should never be used for deslicking if there is excess asphalt on the surface.

Double Surface Treatments

Design quantities, rates of application, for double surface treatments also are tabulated. The designer should select the treatment best suited to the particular project. Double surface treatments are little, if any, thicker than single surface treatments using the same aggregate size. Because of the interlocking of aggregate in the first and second layers, they are considerably more durable and more resistant to traffic.

Quantities are provided for four double surface treatments. Aggregate sizes are No. 5-No. 7, No. 57-No. 8, or No. 9M, No. 6-No. 8 or No. 9M, No. 7-No. 9M or No.8.

No. 5-No. 7 size will provide a rather coarse textured treatment about 1 inch thick. It is the thickest and strongest of asphalt/aggregate surface treatments. It may be considered for use over primed granular bases or over badly cracked pavement that is sufficiently stable to support traffic loads.

No. 57 - No.8 or 9M sizes are used in the same situations appropriate for No. 5-No. 7 sizes. No. 57 has a greater distribution of particle sizes and is somewhat more difficult to use than No. 5 but where No. 5 size is not available, No. 57 can be used. The No. 8 size is used for the second aggregate application because No. 7 size is already blended into the No. 57 stone. This provides a slightly finer surface texture. This treatment also will provide about 1 inch thickness.

No. 6 - No. 8 or No. 9M sizes provide a tough treatment having a thickness of about 3/4 inch. It also is excellent for use over primed granular bases. Its resistance to traffic is good and it is frequently used at locations subject to considerable truck traffic. Its texture is slightly finer than the previous treatment.

No. 7 - No. 8 or No. 9M sizes provide a reasonably fine textured treatment about 1/2 inch thick. It is not as effective on primed granular bases as previously discussed treatments, but it is sometimes used for that purpose. It is excellent for sealing, or improving surface properties, on relatively sound pavement structures. The interlocked layers provide good traffic resistance.

Other Design Information

There is a rather simple and reasonably accurate procedure for determining aggregate application rate for single surface treatments or the first aggregate application of double surface treatments. This consists of constructing a shallow tray having an area of 1 square yard, or some fraction of 1 square yard. The aggregate to be used is carefully placed one particle deep in the tray. Hand pressure is used to fill the tray as completely as possible. The stone in the tray is then weighed to determine the pounds of aggregate required to cover one square yard one particle deep. The procedure is repeated three times, or more, and the average weight determined. Usually, 5 to 10 percent waste is added to the average weight to provide the application rate for stone. This procedure is better than depending only on tabulated quantities.

Other Asphalt/Aggregate Applications

Triple surface treatments and Cape Seals were briefly discussed earlier. It is not believed that they will be widely used in Kentucky and their design is not included in this manual.

Premixed Surface Treatments

Slurry seals, hot plantmix seals, and cold plantmix seals all require laboratory design procedures. The Kentucky DOH provides design procedures for slurry seals and hot plantmix seals. When these seals are used, the local agency should require the contractor to supply design data before the work begins. If the agency is doing the work with its own forces and lacks laboratory facilities, a commercial laboratory may be engaged to design the mixtures. In some cases, the asphalt supplier may be of assistance in designing these mixtures.

Cold plant mixtures can be designed by laboratory procedures with acceptable accuracy. Unfortunately, the needed equipment and knowledge is not generally available in Kentucky because this type mixture is not widely used. Some emulsion suppliers may be able to do mixture designs if the aggregate is supplied to them. There are also formulas, based on aggregate gradation, that are reasonably reliable in most cases. One such formula is given below.

$$P = 0.05A + 0.1B + 0.5C$$

Where

P = Percent by weight of asphalt emulsion based upon weight of aggregate.

A = Percent of aggregate retained on No. 8 sieve.

B = Percent of aggregate passing the No. 8 sieve and retained on the No. 200 sieve.

C = Percent of aggregate passing the No. 200 sieve.

Asphalt Applications

This group includes fog seal, prime coat and tack coat. None of these require design in the usual sense. Ranges of application rates are stated but the actual rate applied is based on the judgement and experience of the user. There are, however, a number of things to consider before deciding what rate to use. These are design considerations and are discussed in the following.

Fog Seal Design. As stated earlier, fog seals are made with diluted slow setting emulsions, SS-1h or CSS-1h. Either will function well with most surfaces since most of the asphalt should penetrate into surface pores. The cationic emulsion may break somewhat quicker.

The designer must decide what dilution rate to use. This depends on both the size of the surface pores and the surface texture. The decision is not an easy one because there is no simple way to measure pore size or texture. If the designer can observe the pavement as it dries after a rain, a better opinion of its porosity can be gained. Usually it is better to use dilution rates ranging from 2 to 3 parts water to 1 part emulsion. Some agencies use 1 to 1 dilution rates for this purpose but this may provide too much asphalt in many cases. It is safer to use the higher dilution rates and avoid the possibility of leaving excess asphalt on the surface. If the pores are not adequately sealed, a second application can be made later.

The application rate also must be selected. This may range from 0.10 to 0.20 gallons per square yard. In most cases, 0.10 gallon per square yard will provide enough liquid to penetrate pores without appreciable runoff. In some cases where the pavement is quite porous more can be used, up to about 0.15 gallon per square yard. On such pavements it is better to apply 0.10 gallon or a little less per application and make two applications spaced about a day apart. This approach is always best on relatively steep grades where preventing runoff is difficult.

Prime Coat Design. The ranges of application rates usually needed is 0.20 to 0.50 gallons per square yard. Within this range, a specific rate must be selected on the basis of judgement and experience. Open granular surfaces will need near the maximum quantity. Dense granular surfaces will need near the minimum. It is intended to provide that quantity that will be completely absorbed within 24 hours.

Tack Coat Design. The application rate for tack coats varies from 0.05 to 0.15 gallons per square yard of 1 to 1 water diluted SS-1h or CSS-1h. The minimum needed to coat the surface should be used. Generally this is about 0.10 gallon.

Most of the material applied is water, about 70 percent, that must evaporate before the surface is paved. In humid or cool weather the drying process can be very slow. Under such conditions, undiluted emulsion may be used. This reduces the water to about 40 percent of the total liquid applied and reduces drying time. If this is done, the application rate should not exceed 0.10 gallon per square yard.

Table No. IV

APPLICATION RATES OF ASPHALT AND
AGGREGATE FOR SINGLE SURFACE TREATMENTS*

Approximate Thickness, inch	Nominal Size Of Aggregate inch	Standard Stone Size	Quantity of Aggregate lb./yd.2	Quantity of Asphalt gal./yd.2	Type & Grade Of Asphalt
3/4	3/4 to 3/8	6,67. 68	40 - 50	0.40-0.50	RS-2, CRS-2 RS-2s,CRS-2s HFRS-2 AE-90s
1/2	1/2 to #4	7.78	25 - 30	0.30-0.45	RS-2, CRS-2 RS-2s,CRS-2s HFRS-2 AE-90s
3/8	3/8 to #8	8,9M	20 - 25	0.20-0.35	RS-2, CRS-2 RS-2s,CRS-2s HFRS-2 AE-90s
3/16	#4 to #16	9	15 - 25	0.15-0.25	RS-1, CRS-1 RS-2, CRS-2 RS-2s,CRS-2s HFRS-2 AE-90s
3/32	Sand	ConcreteSand	12 - 18	0.12-0.20	RS-1, CRS-1

CORRECTIONS FOR SURFACE CONDITIONS

Texture	Correction, Gal./Yd.2
Flushed Asphalt	-0.01 to -0.09
Absorbant - slightly porous, oxidized	+0.01 to +0.05
slightly pocked, porous, oxidized	+0.04 to +0.06
badly pocked, porous, oxidized	+0.06 to +0.09

Table No. V

APPLICATION RATES OF ASPHALT AND
AGGREGATE FOR DOUBLE SURFACE TREATMENTS

Approximate Thickness, inch	Nominal Size of Aggregate, inch	Standard Stone Size	Quantity of Aggregate lb./yd.2	Quantity of Asphalt gal./yd.2	Type and Grade of Asphalt
1	1 to No.4				
First Application		5	40 - 50	0.30-0.40	RS-2,CRS-2
Second Application		7,78	20 - 30	0.40-0.60	RE-2s,CRS-2s HFRS-2
Total Application (Min.)			70	0.80	AE-90s
3/4	3/4 to No.8				
First Application		6,67,68	35 - 45	0.20-0.35	RS-2,CRS-2 RS-2s,CRS-2s
Second Application		8,9M	20 - 25	0.40-0.60	HFRS-2
Total Application (Min.)			60	0.70	AE-90s
5/8	1/2 to No.8				
First Application		7,78	30 - 40	0.20-0.30	RS-2,CRS-2 RS-2s,CRS-2s
Second Application		8,9M	15 - 20	0.35-0.45	HFRS-2
Total Application (Min.)			50	0.65	AE-90s
1/2	3/8 to No.16				
First Application		8,9M	25 - 35	0.20-0.30	RS-2,CRS-2
Second Application		9	10 - 15	0.30-0.40	RS-2s,CRS-2s
Total Application (Min.)			40	0.60	HFRS-2 AE-90s

Notes for Tables IV and V:

1. These Quantities of Asphalt covers the average range of conditions including primed granular baces and old permanent surfaces from slightly porous and oxidized to slightly pocked, porous, and oxidized. Quantities may need adjustment for extreme surface conditions and for very absorptive aggregate.

2. Generally, the lower application rates of asphalt and higher rates of aggregate shown in the table should be used for cover aggregate having gradations on the fine side of the specified limits. The higher application rate for asphalt and the lower application rate for aggregate should generally be used when cover aggregate gradation is on the coarse side of the specified limits.

3. Weight of aggregate shown in the table is generally suitable for Kentucky aggregate. If very heavy, or very light, aggregate is used, quantities must be adjusted to provide essentially the volume of aggregate represented in the table.

4. Asphalt quantities do not include adjustments for extreme surface conditions. These adjustments should be added to or deducted from the normal quantity selected.

V. CONSTRUCTION OF SURFACE TREATMENTS

The decision making process has been completed. It has been determined that a surface treatment can best satisfy the need. The type that will best provide the needed improvement has been selected. It is now time to budget funds for construction and to fit the project into the program. This part of the process should be well in advance of the desired construction date. Usually lead time of at least one year is desirable.

Before construction can start, a number of specific preliminary considerations must be evaluated. Among these are: (1) Will the work be done by agency forces or by contract? (2) What is required to properly prepare the pavement for surface treatment? (3) Are the needed aggregate(s) and asphalt(s) available? (4) Is the needed equipment available in the agency or can be rented for the project? (5) Are the personnel to do the work properly trained? (6) How should the construction be organized to assure good results? The answers to these questions have an important bearing on both construction and performance of the surface treatment.

CONTRACT OR AGENCY CONSTRUCTION

This decision is largely one of economics, assuming that good work can be obtained either way. Is the agency staffed and equipped to do the work? If the answer to this is yes, then in house forces should be considered. If the answer is no, it may be more expensive to equip, staff and train personnel than to contract the work. If contract work is considered, are there competent contractors available? These questions can only be answered locally where all parts of the problem are known.

PREPARATION FOR SURFACE TREATMENT CONSTRUCTION

Preparation for surface treatment is made in two specific phases and both are very important. First, the existing surface and roadway should be corrected as necessary. Second, the surface must receive final preparation just prior to construction.

Drainage

Correction of the existing surface and roadway begins with correcting drainage as needed. All side ditches, or storm drains, should be open and provide effective drainage of storm water. If any water is seeping beneath the roadway and creating soft spots, ditches or storm drains should be corrected and, if needed, under drains installed. If shoulders are too high and are trapping water at the pavement edge, they should be bladed down to permit surface water to reach the side drain. This work can and should be done with agency forces well in advance of constructing the surface treatment. If the agency's work load is too heavy to do this work in advance, it can be done as the first task of the contractor. In any case, all such corrective work should be completed before the surface treatment is constructed.

Correction of Existing Paved Surface

It is apparent that any weak spots or areas must be patched in a manner that will provide a surface of uniform strength throughout. This may require patching and strengthening of a few or many areas. This work can best be accomplished as part of the corrective maintenance program well in advance of the planned construction. When contract construction is planned, corrections may be done as above or may be done as part of the contract.

Rutted or badly warped surfaces cannot be effectively paved with surface treatments. These must be leveled and shaped beforehand. On some roads or streets, this will be a major consideration. A

leveling course of hot-mix or cold-mix can often be blade spread to correct such problems. Towed spreaders or more sophisticated equipment may be used effectively. These corrections can also be done well in advance or as part of the surface treatment project.

Crack Sealing

Surface treatments can seal and bridge narrow cracks fairly well. They cannot be effective if the cracks are 3/8 inch wide or more. These cracks should be cleaned and sealed before the construction is started. If this is not done, the cracks will usually reflect through, breaking the intended seal and shortening its life.

Preparation of Granular Surfaces

When granular base, such as traffic-bound gravel roads, are to be surface treated, some additional operations must be considered. Usually, such bases are mixtures of soil and aggregate and are variable in thickness. To perform properly when surface treated, need for two corrections must be evaluated. First, a substantial layer of clean aggregate may be needed to reduce the effect of soil in the existing layer. Second, how thick must the total aggregate layer be to provide the needed structural strength at the specific location? If additional aggregate is needed, as it probably will be, the needed thickness should be carefully constructed. Usually, the existing surface should be shaped and thoroughly compacted to provide a uniform surface on which the added thickness may be constructed. Whether aggregate is added or not, the final surface also must be shaped to assure uniform crown, cross-section and longitudinal section. Compaction must be very thorough.

When shaping is completed, the granular surface must be primed. It will require at least 48 hours for the prime coat to cure. If rainfall occurs or humidity is high, it may take longer. For the best results, let the prime cure until the surface is hard and firm.

When this condition is reached, construction of the surface treatment can proceed. Remember, primer can be messy and the users of the road should be warned in advance if possible. Always use "Fresh Oil" signs at each end of the project and spaced within long projects.

Cleaning Surface

Just before surface treatment construction is started, the surface must be cleaned of all loose material, dirt, dust, leaves, or other debris. Thorough cleaning is essential. If dirt is caked on the surface, it may require washing to fully remove it. At the very least, the surface should be thoroughly swept with a power broom. Remember, the emulsion must thoroughly wet the surface. Any foreign material on that surface prevents emulsion from doing its job and results in damage to the surface treatment.

All the above operations are necessary to assuring the selected surface treatment will provide the intended performance. Careful preparation is an essential part of the operation. It may start a year or more in advance of construction and is not completed until just prior to construction.

MATERIALS FOR SURFACE TREATMENT CONSTRUCTION

These materials have been discussed previously. Now the decision has been made as to the type of surface treatment to use. Suppliers must be contacted to assure the needed asphalt and aggregate will be available. It must be determined who will deliver the materials and in what type equipment. Can the trucks delivering aggregate also be used to spread the aggregate or must it be stockpiled and reloaded? Can the emulsion transport stay on the job until all material is off-loaded into the distributor or must it be off-loaded into storage tanks? All such details

must be resolved in advance to permit detailed planning and scheduling of the actual work. For best results, enough material must be on the job site at all times to avoid interruption of the work.

EQUIPMENT FOR SURFACE TREATMENT CONSTRUCTION

Equipment needed for surface treatment construction varies with respect to the type treatment to be used. The following will identify that equipment, its calibration if required, emphasize essential functions, and describe principles of its use.

For asphalt/aggregate applications, single and double treatments, four major items are used in the work. These are the asphalt distributor, the aggregate spreader, rollers and the power broom. Of only slightly less importance are trucks for aggregate and transports for emulsified asphalt.

Requirements for premix surface treatments vary. Hot plantmix seals require a standard hot-mix plant for production and standard lay down equipment for construction. These requirements are specified in Kentucky DOH Standard Specifications, Sections 404, and will not be repeated here.

Cold plantmix seals require a mixing plant that can accurately proportion aggregate, emulsified asphalt, and water, if needed, to produce the mixture. Lay down and compaction equipment is the same needed for hot mix.

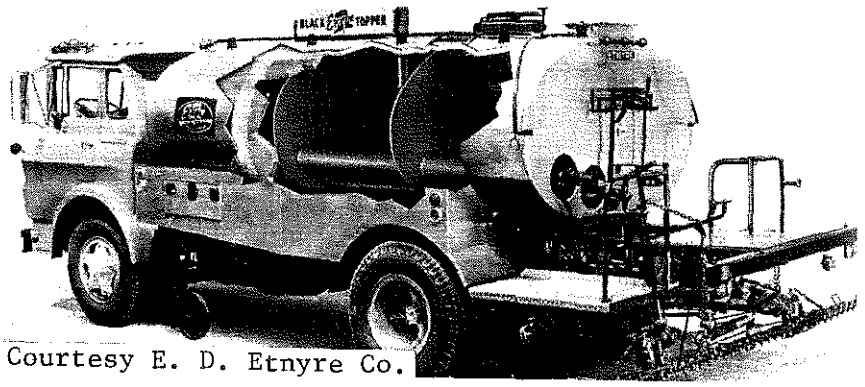
Slurry seal requires blending equipment for the aggregate and a slurry seal machine that accurately blends aggregate, asphalt, water, and additives if needed. The same machine mixes and spreads the slurry.

All asphalt seal applications (such as fog seal) require only an asphalt distributor.

Asphalt Distributor

This is probably the most important piece of equipment needed. Its function is to uniformly spread asphalt on the surface to be treated at the intended rate, gallons per square yard. Usually the distribution is truck mounted, but it may be trailer mounted. There are a number of manufacturers of such equipment and each produces several models that may vary in size and operating equipment. It is essential that the operator's manual be carefully studied to assure the most effective use of the equipment.

All asphalt distributors have a number of systems in common. Although they may differ in principal, size, and equipment, when properly used all can uniformly spray asphalt at the desired application rate.



Courtesy E. D. Etnyre Co.

FIGURE 9 -- ASPHALT EMULSION DISTRIBUTOR

Principals of Operation. Some distributors operate on the basis of constant line pressure in the spraying system. With this type equipment, the line pressure is established and maintained to provide the desired discharge rate which will produce a uniform spray fan at each nozzle. Pressure may be varied as necessary to achieve the desired condition. Once the proper line pressure is determined, it can be set and the distributor controls will maintain that pressure. The rate of application is then dependent upon the quantity of emulsion being delivered through the nozzles, per unit of time, and the truck speed. Truck speed is varied as necessary to provide the desired rate of application. This system does not require adjustment for the length of spray bar used because the constant line pressure provides equal pressure at all nozzles regardless of the number used.

Other distributors operate on the basis of gallons per minute delivered by a positive displacement pump. The pump speed, RPM, may be changed to deliver more or fewer gallons of emulsion per minute. With this system, the pump speed or the rate of forward motion must be changed when the length of the spray bar, the number of nozzles, is changed. If the number of nozzles is increased, pump speed must be increased to deliver the proper quantity of emulsion to each nozzle.

Either of the above systems may be used effectively. In some makes and models of each system, a one man crew, the driver, operates the entire system through controls mounted in the truck cab. Other require two men, a driver who controls forward speed and an operator on the rear platform who controls pumping and spray bar.

Tank and Heater System. All distributors should have insulated tanks and indirect heating systems to maintain the proper emulsion temperature and thus its viscosity. Tank size

may vary from a few hundred gallons to several thousand gallons. Selection of the proper size depends both on the amount of surface treatment to be done in an average year and other uses for this equipment.

It is very important to maintain the emulsion at a constant temperature within the spraying range shown in Table VI. This provides for uniform quantities delivered to the nozzles at any given combination of rate control settings. A thermometer is mounted in a well on the tank to permit temperature determination.

When emulsion is delivered by the supplier, it should be within the proper application temperature range. In most cases, heating will only be required on the initial loading of the distributor, if then. The heater is not intended to provide large temperature increases. Surface treatment construction should never have to stop while the distributor heating system makes major temperatures increases.

The tank also must have a gage, or gages, to measure volume of emulsion in the tank. Some have float gages that can be read from the rear of the tank. All have stick gages that are inserted through the top of the tank. It is essential to know the exact gallonage in the tank before and after each spray application to measure the amount of emulsion applied.

TABLE VI
APPLICATION TEMPERATURES FOR ASPHALT USED IN SURFACE TREATMENTS

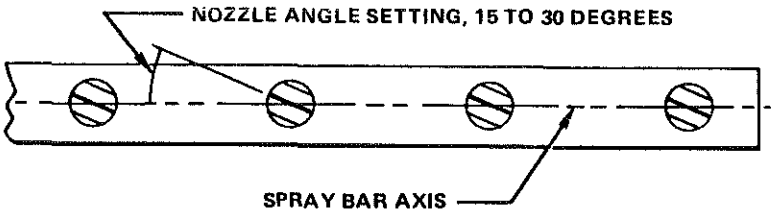
Type & Grade of Asphalt	Spraying Temperature, F°
RS-1	70-140
RS-2	125-185
CRS-1	125-185
CRS-2	125-185
HFRS-1	125-185
HFRS-2	125-185
RS-26	125-185
CRS-2s	125-185
SS-1	70-160
SS-1h	70-160
CSS-1	70-160
CSS-1h	70-160
Primer L	60-120

Pump Systems. All distributors have positive displacement pumps for spraying and circulating emulsions as well as pumping material into or out of the tank. These pumps are carefully designed to provide proper clearances to avoid binding. There are numerous kinds of pumps but each can do the job if adjusted and maintained as the operating manual directs. Pump controls include tachometer and pressure gages which determine pump output. The pumping system may be powered by connection to the truck transmission or by a separate engine mounted on the distributor rear platform. Actual driving force may be either mechanical or hydraulic.

It is very important to understand your particular pumping system. It must function effectively. If it does, and only then, good surface treatments can be constructed.

Spray Bar Systems. Spray bar systems are usually jointed systems that can spray from about 6 to 12 feet. With extensions they can spray much wider or by closing nozzles much narrower widths can be treated. The system includes the spray bar with nozzles, nozzle cutoff valves, the return lines, plus vertical and horizontal position controls to maintain the proper nozzle height and alignment. The cutoff valves must open and close very rapidly and positively to assure clean starts and stops for spray applications.

The nozzles must all be of the same type and size. They also must be set at the exact angle recommended by the manufacturer to avoid spray fans interfering with each other and to assure proper coverage. The nozzle generally used has an opening of 1/8 inch but other sizes are available. The opening must be clean or the intended amount of asphalt will not be sprayed. Most spray bars have nozzle spacing of 4 inches but some are spaced 6 inches apart. Proper nozzle settings are shown in Figure 10 on the next page.



Courtesy The Asphalt Institute

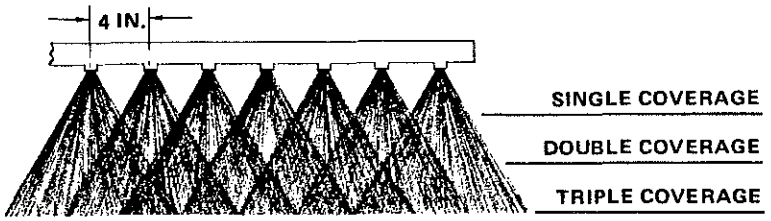
FIGURE 10 -- PROPER NOZZLE ANGLE SETTING

Spray bar height must be adjusted to provide, for nozzle spacing of 4 inches, either a double or triple overlap of spray fans. Either may be used with the triple overlap being the more common. When spacing is 6 inches only the double overlap is used. The overlap must be exact or streaking will occur. As the emulsion in the tank is sprayed, the height of the bar may increase due to reduced weight. It must be adjusted to maintain the exact overlap of spray fans. Figure 11 on page 59 shows correct and incorrect height adjustment of spray.

Control Systems. There are several controls that regulate the rate of application. Some are located in the truck cab and some may be there or on the rear platform. They may include a tachometer to measure forward speed and distance traveled, tachometer to measure pump RPM, and a pressure gage to measure line pressure and possibly others. Remember that the rate of application is dependent on a constant forward speed and either constant pump RPM or constant line pressure. The controls furnished with each distributor will permit the operator to determine rates and pressure. Some distributor models have interlocking systems that, once application rate is set, the volume of emulsion delivered by the pump will automatically be adjusted if the forward speed varies to maintain a constant application rate. Most do not interlock and the operator must maintain, as nearly as possible, the exact settings required.

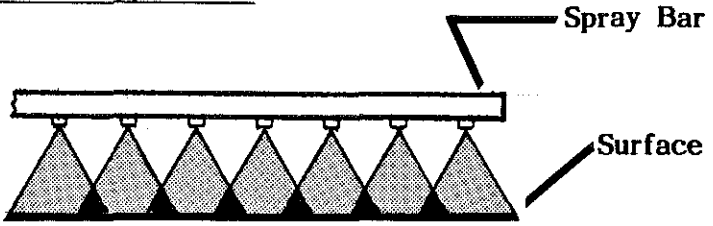
FIGURE 11 -- SPRAY BAR HEIGHT

Correct Height -- Uniform Application



Note: Exact single, double, or triple laps are required for uniform application. Single lap is rarely used. Double lap may be done with 4" or 6" nozzle spacing. Triple lap is generally done only with 4" nozzle spacing.

Incorrect Height -- Non-Uniform Application



Bar too high, causing ridge of asphalt.

Bar too low, causing uncoated streak.

Note: Incorrect bar height causes streaking in surface treatments. Single lap coverage is shown, but improper bar height for double or triple coverage will also cause streaking.

Bar set for correct single lap coverage.

Aggregate Spreaders

The second major piece of equipment for surface treatments is the aggregate spreader. It is used only for asphalt/aggregate applications. There are many types including truck-mounted vane spreaders and tailgate spreader boxes, truck-pushed spreaders and self-propelled spreaders. The essential requirement for all spreaders is the capability of uniformly spreading aggregate at the intended quantity per square yard.

Truck Mounted Vane Spreaders. Truck-mounted vane spreaders are the least accurate and least desirable equipment. The rate of spread is entirely dependent upon the truck driver's ability to control his backing speed and alignment. Also, there is no control on quantity of aggregate discharged except the tailgate opening and angle of the bed. Good work is rarely done with this type spreader (see Figure 12).

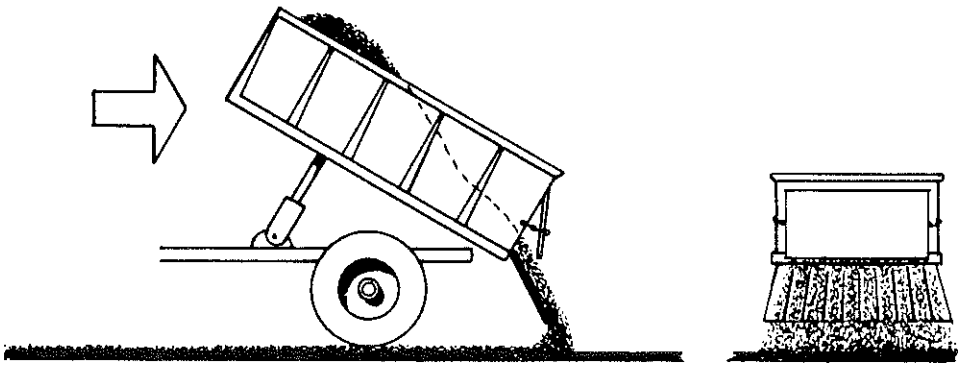


FIGURE 12 -- TAILGATE VANE SPREADER

Courtesy The Asphalt Institute

Truck-Mounted Spreader Boxes. Truck-mounted spreader boxes, as seen in Figure 13, are an improvement over vane spreaders. The box is attached to and carried by the truck. Aggregate moves from the bed into a hopper which has an adjustable bottom gate. The gate is opened or closed to provide a slot for the aggregate to fall through at a fairly constant rate. Again, the driver must be very good. He must estimate the speed required to uniformly spread the falling stone in the proper amount. The hopper gate may be opened or closed to adjust rate by controls in the cab or manually from each side of the truck. When using this type equipment good work is difficult but can be done if the project is constructed in short sections.

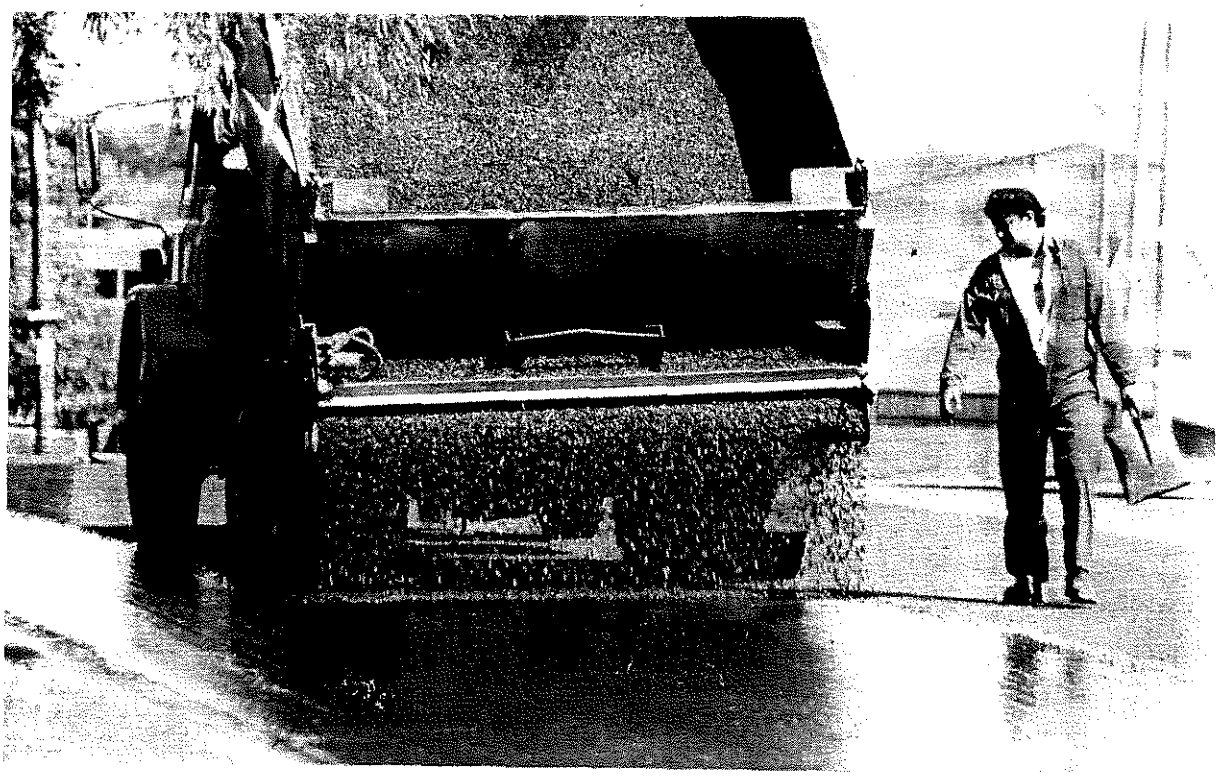
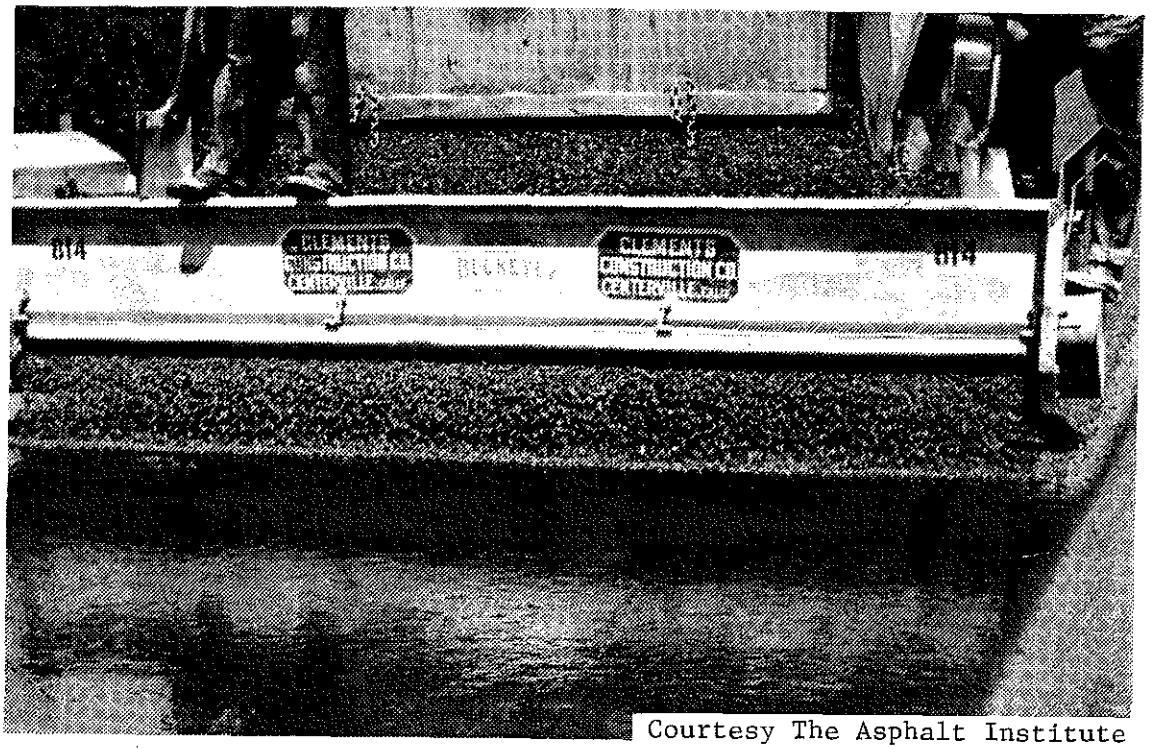


FIGURE 13 -- HOPPER TYPE TAILGATE SPREADER

Courtesy Chevron U.S.A. Inc.

Truck-Pushed Spreader Boxes. Truck pushed spreader boxes (Figure 14) are capable of doing very good work if good truck drivers are available. These are wheel-mounted boxes that are attached and pushed by the aggregate truck. They have rotating feeder bars at the hopper bottom that feeds aggregate to an adjustable gate. The feeder bar is driven through a chain drive by the wheels on the box. The gate can be adjusted to provide the rate of discharge required. This is probably the simplest equipment that consistently can produce reasonably acceptable results. Usually excessive aggregate is spread to be sure complete coverage is obtained. Its greatest handicap is that it must be operated rather slowly. This often results in the aggregate spread falling too far behind the asphalt application. Short sections must be worked and production is slowed. This is rather effective equipment but not equal to the next item.

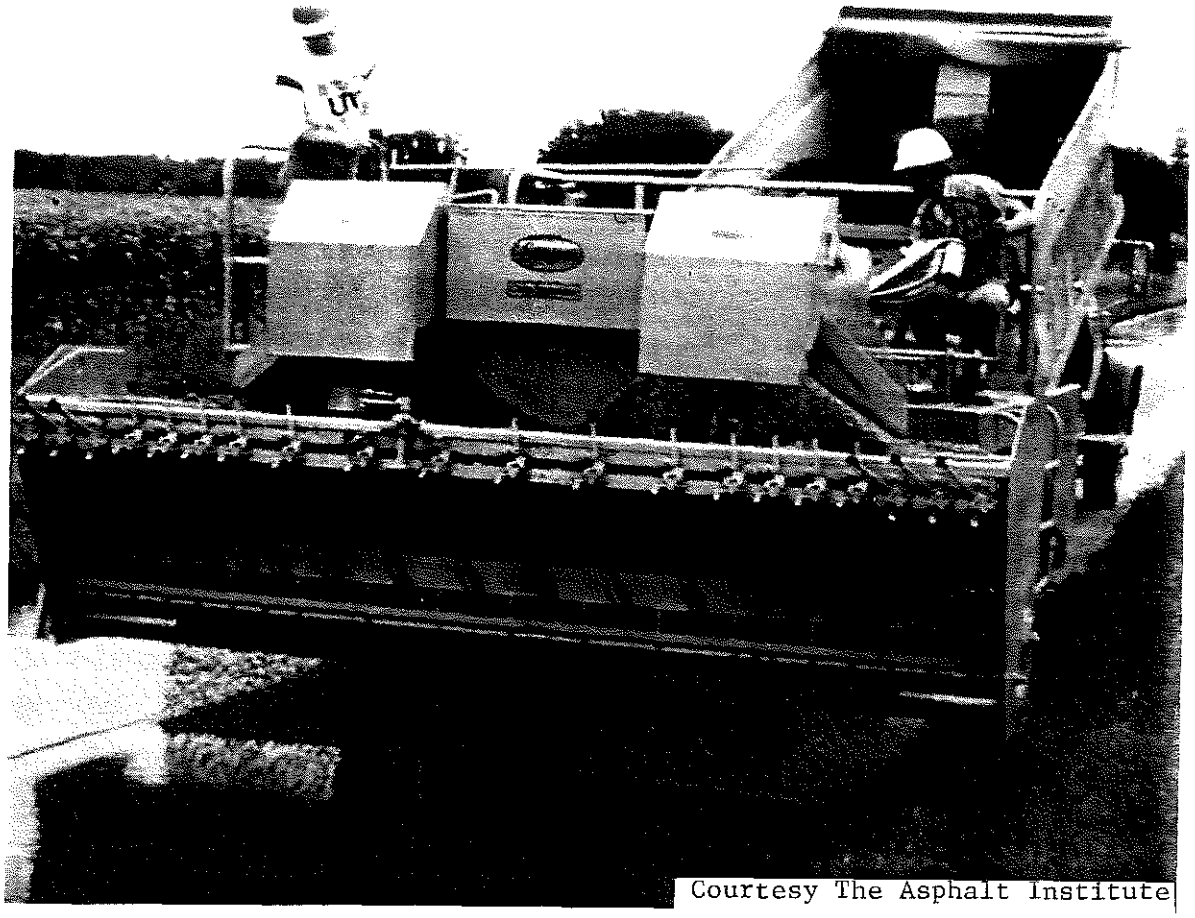


Courtesy The Asphalt Institute

FIGURE 14 -- TRUCK PUSHED SPREADER BOX

Self-Propelled Spreaders. Self-propelled spreaders (Figure 15) are far superior to other spreading equipment. They have enough power to tow the aggregate truck and operate all systems on the spreader while maintaining enough speed to keep up with the asphalt distributor. This permits spreading cover aggregate well before the emulsion breaks and assures the best result. This type spreader has a positive feed that can be calibrated to deliver the proper quantity of aggregate. Production rates are high and results good.

This is also the most expensive equipment. When large quantities of work must be done, they reduce the unit cost. For small quantities of work the unit cost goes up considerably. For these reasons, purchase of this equipment may not be justified. It may be possible to rent self-propelled spreaders, and their operating crew, or to contract for spreading only.



Courtesy The Asphalt Institute

FIGURE 15 -- SELF-PROPELLED AGGREGATE SPREADER

Rollers

Self Propelled Pneumatic Rollers. Self-propelled pneumatic rollers (Figure 16) are essential for good construction of asphalt/aggregate applications. Seven-, nine-, or eleven-wheel rollers may be used if their weight is in the range of 8 to 15 tons and tire pressure can be maintained within the range of 45 to 90 psi. A tire pressure of about 60 psi is often preferred for low to medium traffic roads. Weight of the roller may depend on the structural thickness of the pavement being treated. Thicker structures justify heavy rollers in the range noted. If the structure is thin, keep the roller light. Wobble wheel rollers cannot be permitted. Operational speed should be maintained within a range of 2 to 5 mph.

Courtesy The Asphalt Institute

FIGURE 16 -- PNEUMATIC-TIRED ROLLER

Steel Wheel Rollers

Steel Wheel Rollers, tandem, are sometimes used for asphalt/aggregate applications. They will bridge over low spots and fail to uniformly seat the aggregate. They also tend to break aggregate creating more fines, which is undesirable. If used, the roller weight should be 6 to 8 tons for these applications. The pneumatic roller will do better work and is preferred.

Tandem steel wheel rollers in the weight range of 8 to 10 tons are preferred for plantmix seals, either hot or cold.

Power Brooms

Power Brooms are essential for cleaning the surface before surface treatment construction and for the removal of any excess aggregate placed during the treatment. They may be either towed or self-propelled types. The broom should have rather stiff bristles and must be in excellent condition to clean effectively.

Trucks

Trucks are also important items of equipment. They must be in excellent operating condition with clean, undamaged dump beds. Drivers must be familiar with their part of the job. This varies with the type spreading equipment used. With some procedures the drivers will make or break the job.

Other Equipment

Other Equipment will always include hand equipment such as brooms, and shovels and may include numerous other items. Measuring tapes, stakes, and flagging may be needed to determine the length of spread and to mark locations for starting and stopping. Building paper for joint construction may be needed.

Trays for calibration or checking rates of spread may be needed. Anything that may be needed should be on the job when it starts.

Safety Equipment

Safety Equipment is essential to every job. This includes hand held flags and signs, flashing arrows, barricades, cones, lead trucks, etc. for traffic control during construction. It also includes warning signs to alert drivers approaching the work and within the project area. This is essential for protection of workers on the project as well as for the using public.

CONSTRUCTION OPERATIONS

Preparation for the project has been completed. It is now time to do the actual construction. Planning and coordination of construction operations is very important. All equipment must be checked and scheduled. All personnel must be instructed as to what they will do and how their job fits into the overall construction. Suppliers must be prepared to deliver needed materials at the proper time and place. All such details must be resolved before the construction date.

PRE-CONSTRUCTION CONFERENCE

When the above details are worked out satisfactorily and just prior to beginning the work, a pre-construction conference should be held. The purpose of this meeting of key personnel is to coordinate all parts of the construction. Key personnel must include all supervisors and foremen. It is usually valuable to also include equipment operators. It is essential to include suppliers who will deliver materials to the job. The detailed work plan and scheduling is presented and discussed. Some modifications of that plan may be desirable to assure a smoother, more continuous operation. Now is the time to let all concerned know how they fit into the project and just what is expected from them.

MATERIALS SUPPLY

Regardless of the type surface treatment to be constructed, it is essential that the required materials are on site and ready to use as needed. Otherwise, stop and go construction will result rather than the continuous operation that produces the best construction. The materials used differ with the type surface treatment being constructed. The need for continuous operation, and thus supply, applies in all cases.

Aggregate Supply

Aggregate supply for asphalt/aggregate applications must be effective. No asphalt can be sprayed unless the needed quantity of cover stone is at the work site ready to be loaded into the spreader. Can the supplier deliver the needed stone without interrupting continuity of construction? If such delivery can be assured, this may be the best procedure. If continuous delivery cannot be assured, the aggregate must be stockpiled at appropriate locations along the project. Loading equipment must be available to quickly reload trucks. In either case, enough trucks must be used to supply cover stone to the spreader as needed.

Asphalt Supply

Asphalt supply for asphalt or asphalt/aggregate applications should be scheduled with the supplier for delivery when and where needed. Normally these materials should arrive at the application temperature, be transferred to the distributor and applied as quickly as possible. This is the most effective way to use all emulsions. If delivery cannot be scheduled to fit the work plan, it will be necessary to store on site in insulated tanks equipped to maintain the proper temperature and to circulate the material. Storage should be avoided if possible.

Premix Materials

Premix materials require the same availability. Slurry seal aggregates and asphalt must be on or very near the job to assure as nearly continuous operation as possible. Hot or cold plantmix materials should be supplied to the paver at a rate that permits, as nearly as possible, continuous operation.

ASPHALT APPLICATION

Asphalt application cannot start:

(1) until the aggregate spreader is in place, and ready to move, just behind the starting location;

(2) the roller(s) are also in line and ready to go;

(3) distributor tank is filled with asphalt at the proper application temperature;

(4) distributor settings and forward speed have been set to produce the desired rate of application; and

(5) the length of spread has been determined and is within the capacity of the distributor.

Before starting movement, stick the tank to determine how many gallons it contains. For best results, place building paper across the lane to be sprayed and start spray on the paper when work begins. It is best to also put building paper across the lane at the end point and cutoff spray on that paper. While actually spraying one lane, stop all traffic and clear the other lane.

At the end of the run, stick the tank again to determine gallons remaining. The difference between initial gallons and final gallons is the quantity sprayed. This quantity, divided by the area sprayed in square yards, is the actual rate of application. Compare this value with the design rate. If the actual rate is within 10 percent of the design rate, the settings used are correct. If outside 10 percent tolerance, adjustment must be made. Usually the adjustment needed is to distributor speed.

Once the distributor starts, it should be stopped before the intended end point for only three reasons. If it is observed that the spray from any nozzle is not uniform, stop. Correct the problem before continuing the run. The same applies to any malfunction of the distributor.

The second reason to stop is when the rate of application is being checked with a sampling tray. The tray has been placed far enough from the starting point to assure that the distributor is moving at the intended forward rate. Tray is located about mid-width of the application. As soon as the distributor passes the tray, the spray is cut off. The tray is weighed and weight of the empty tray deducted to find the weight of asphalt in the tray. Weight is determined per square yard. Divide that weight by the weight of one gallon of asphalt (supplier furnishes this weight) to find the actual application rate. Use the hand spray to coat the sampled area. If correction to the distributor speed is needed, reset speed, move back to the cutoff point and restart application.

The third reason to stop is malfunction of the aggregate spreader. If the aggregate can't be spread immediately, stop the distributor as quickly as possible. Sometimes horn signals can be used for this purpose. Any area that has been sprayed with

asphalt but not covered with aggregate before the emulsion breaks has to be considered a fat pavement when work is restarted. Adjustment of quantities and possibly aggregate size, must be made.

Spreading Aggregate

Spreading aggregate should be properly set and ready to move immediately after the asphalt has been sprayed. The quicker the cover stone is in place, the better the results. The spreader should move, as nearly as possible, at the same rate as the distributor. In any case, the cover stone must be placed before the emulsion breaks or it will not be properly wetted by the emulsion. In very hot, dry weather, time to break can be as short as 3 to 5 minutes. Always try to spread cover aggregate within one minute to be sure of good results. If late spread occurs, check the wetting by carefully lifting coarse particles to see if they are wet with asphalt. Check again after rolling when at least half of the aggregate particle should be coated. If this degree of coating is not reached, aggregate loss under traffic should be expected. In some cases, a fog seal may be applied to provide better embedment of cover stone.

Aggregate spread rates can be checked with a sampling tray similar to that used for asphalt or from the weight of cover stone applied. With the latter method, the weight of each load is determined from the weigh ticket. That weight, in pounds, divided by the area covered, in square yards, is the average application rate. This check should be made several times daily to permit corrections if necessary.

ROLLING SURFACE TREATMENTS

Rolling should always follow spreading very closely. With asphalt/aggregate applications, rolling seats and embeds the aggregate best before the emulsion break has started. It should continue as the break progresses and be completed by the time the break is complete. Several passes of the roller will be required to achieve good density. When rolling is complete, asphalt should be visible between cover stone particles but none should have reached the surface. Careful observation after rolling may indicate a small increase or decrease in the asphalt application rate is desired. Plantmix seals should be thoroughly compacted as quickly as possible.

BROOMING

After the asphalt has set up, any aggregate not cemented in place by asphalt should be broomed off the surface. Usually, it is best to broom the surface during the early morning when the surface is cool. If double surface treatments are being constructed, unbound cover stone should be broomed from the first application before the second application is constructed.

JOB PROTECTION

Once the construction is complete, asphalt or asphalt/aggregate application need protection until curing is well advanced. Length of this period depends on the weather and may be a few days or even a few weeks. During this period speed of using traffic should be held to no more than 25 MPH. It's inconvenient, but the user will greatly benefit from this precautionary measure.

SEQUENCE AND TIMING OF PRE-CONSTRUCTION AND CONSTRUCTION OPERATIONS

The necessary operations for good construction of Surface Treatments have been identified and described in the foregoing. For them to be effectively used, they must also be performed at the proper time.

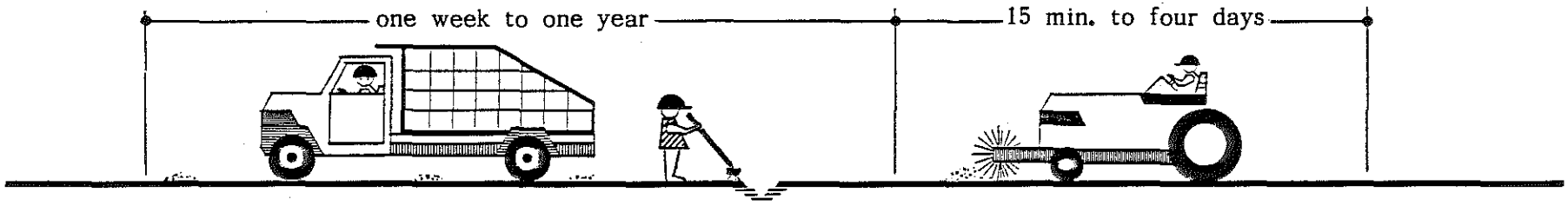
Pre-construction operations have wide ranges in time for them to be performed. This is not true of construction operations. These must be performed very quickly to assure the desired result.

Figure 17 shows the sequence of construction operations in terms of the time available to do them. Note that the asphalt distributor, the aggregate spreader, and the pneumatic roller(s) must be very close together to assure that the aggregate is properly wetted before the emulsion begins to break and is properly compacted before the break is complete.

FIGURE 17 -- CONSTRUCTION SEQUENCE AND TIMING

Preconstruction

Time prior to construction:



(1) Surface Preparation

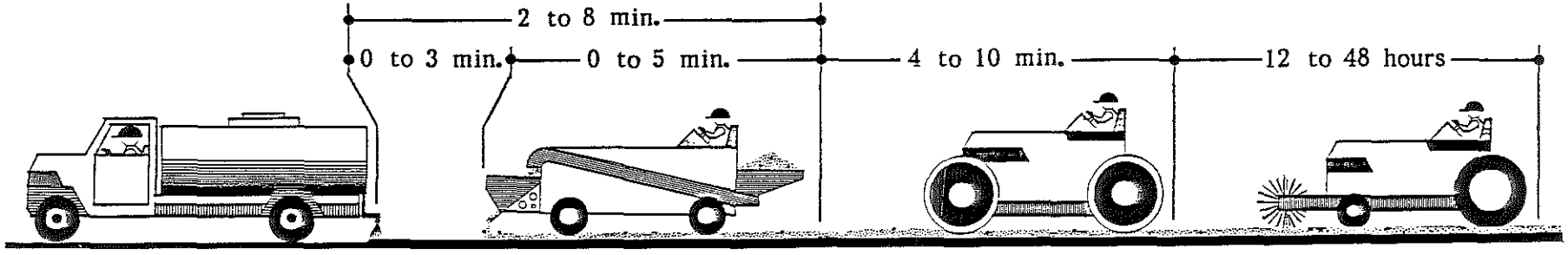
(a) Improve drainage and shoulders.
(b) Reinforce weak areas.
(c) Repair damaged edges.
(d) Seal wide cracks.
(e) Patch as needed.
(f) Correct level and cross-section.

(2) Clean Surface

(a) Blade shoulder material from edges.
(b) Remove all caked or collected material from pavement.
(c) Broom thoroughly just before asphalt application.

Construction

Time after asphalt application:



(3) Asphalt Application

(4) Aggregate Application

(5) Compaction

(6) Sweep

VI. REFERENCES

Asphalt Institute. "Slurry Sealing." Construction Leaflet No. 22 (CL-22), 1978.

Asphalt Institute. "Storing and Handling of Emulsified Asphalts." Construction Leaflet No. 21 (CL-21).

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McLeod, N.W. Seal Coat and Surface Treatment Construction and Design Using Asphalt Emulsions. Asphalt Emulsion Manufacturers Association, 1974.

Marek, C.R. and M. Herrin. "Voids Concept for Design of Seal Coats and Surface Treatments." Highway Research Record No. 361, 1971.

"Road and Paving Materials; Traveled Surface Characteristics." ASTM Standards Vol. 04.03.

APPENDICES

Appendices include specifications, procedures, tables, and graphs that will be useful to the manual user.

A. Glossary of Terms
B. Specifications
C. Specified Tests for Emulsified Asphalts
D. Storage and Handling Emulsified Asphalts
E. Calibration of Surface Treatment Equipment
F. Tips on Single Surface Treatment Design & Construction
G. Miscellaneous Tables

APPENDIX A

GLOSSARY

AGGREGATE

Aggregate: A hard inert mineral material, such as gravel, crushed rock, slag, or sand.

Coarse Aggregate: Aggregate retained on the 2.37 mm (No.8) sieve (approximately 0.10 in.).

Cover Stone: Aggregate used in Asphalt/Aggregate Surface Treatments.

Crushed Aggregate: Aggregate that has been processed through a crushing plant to produce the desired sizes and gradation.

Crushed Sand: Fine angular aggregate produced by crushing of stone, slag, or gravel.

Dense-Graded Aggregate: Aggregate that is graded from the maximum size down through filler with the object of obtaining a bituminous mix with a controlled void content and high stability.

Dust: Very fine, non-plastic, mineral aggregate which is finer than a No. 50 sieve, may be identified as filler.

Fine Aggregate: Aggregate passing the 2.36mm (No. 8) sieve.

Gradation: The distribution of particle sizes, expressed as percentage of the total aggregate weight.

Granular Base: Aggregate layers used for load support in pavement structures.

Grit: A coarse sand containing little or no dust sizes.

Open-Graded Aggregate: Aggregate containing little or no mineral filler or in which the void spaces in the compacted aggregate are relatively large.

Short-Graded Aggregate: An aggregate whose particle size range is limited by specification. Little or no, material is smaller than some specified size. Applies to coarse aggregate only.

Uncrushed Aggregate: Natural gravel that has been processed to produce the desired gradation.

ASPHALT

Asphalt: A dark brown to black cementitious material in which the predominating constituents are bitumens which occur in nature or are obtained in petroleum processing: (ASTM Designation D8). Asphalt is a constituent in varying proportions of most crude petroleums.

Asphalt Cement: Asphalt that is refined to meet specifications for paving, industrial and special purposes. It requires heat to make it fluid.

Asphalt Prime Coat: An application of asphalt primer to an absorbent surface. It is used to prepare an untreated base for an asphalt surface. The prime penetrates or is mixed into the surface of the base and plugs the voids, hardens the top and helps bind it to the overlying asphalt course.

Asphalt Primer: A fluid asphalt of low viscosity (highly liquid) that penetrates into a non-bituminous surface upon application.

Asphalt Seal Coat: A thin asphalt surface treatment applied to an existing bituminous surface.

Asphalt Surface Treatment: Application of asphaltic materials to any type of road surface, with or without a cover mineral aggregate, that produces an increase in thickness of usually less than 1 in.

Cutback Asphalt: Asphalt cement that has been liquefied by blending with petroleum solvents.

Emulsified Asphalt: An emulsion of asphalt cement and water that contains a small amount of emulsifying agent. The agent may be varied in quantity or composition to produce the specific types and grades of emulsion specified.

Polymer-Asphalt Emulsions: Asphalt emulsion made with certain block polymers blended into the asphalt cement used to manufacture the emulsion.

EQUIPMENT

Aggregate Spreaders: Machines for spreading aggregate evenly at a controlled rate on a surface.

Aggregate Trucks: Trucks equipped with hydraulic lifts to dump the aggregate into the spreader.

Asphalt Distributor: A truck, or trailer, with an insulated tank and a heating system. The distributor is made to apply asphalt to a surface in an even spread and at a uniform rate for the whole load.

Asphalt Storage Tank: May be a stationary tank, used to store emulsion until needed. May be an Asphalt Transport used for the same purpose.

Asphalt Transport: A large insulated truck or trailer mounted tank used for delivery of asphalt from the supplier to the user.

Cold Mix Plant: A plant designed to accurately proportion, blend, and mix aggregate and emulsified asphalt to produce the desired cold plantmix.

Hot Mix Plant: A plant designed to accurately proportion, heat, blend, and mix aggregate and asphalt to produce the desired hot plantmix.

Mechanical Spreaders: Spreader boxes mounted on wheels. The spreaders are attached to, and are pushed by, the dump trucks.

Pneumatic-Tired Rollers: Rollers, two-axled and self-propelled, with a number of tires spaced so their tracks overlap while giving kneading compaction.

Self-Propelled Spreaders: Spreaders with their own power units, and two hoppers. The spreader pulls the truck as it dumps its load into the receiving hopper. The aggregate is moved forward by conveyor belts to the spreading hopper.

Steel-Tired Static Rollers: Tandem, or three-wheel, rollers with cylindrical steel rolls that apply their weight directly to the pavement.

Tailgate Spreaders: Boxes with adjustable openings, which attach to and suspend from the tailgates of dump trucks.

Whirl Spreaders: Spreaders that attach to or are built onto dump trucks. Aggregate is fed onto the spreader disc through an adjustable opening and the speed of the disc is adjustable to control the width of spread.

PAVEMENTS AND SURFACE TREATMENTS USE

Asphalt Application: The application of sprayed asphalt coatings not involving the use of aggregate.

Asphalt-Aggregate Applications: Applications of asphalt material to a prepared aggregate base or pavement surface followed by the application of aggregate.

Pavement Structure: All layers of a pavement constructed to support traffic loads. May include granular base, asphalt base, and asphalt surface courses. Granular based pavement structures have one or more layers of aggregate base beneath an asphalt surface. Full depth pavement base and surface are both asphalt-constructed on the subgrade.

Dust Laying: Diluted slow-setting emulsion, sprayed on an untreated surface to prevent dust. The asphalt penetrates and coats the fine particles to relieve the dust nuisance temporarily. This treatment also is called dust palliative.

Grit Seal: A single surface treatment using a fine gravel aggregate as cover stone.

Hot Asphalt Emulsion Mix: A mixture of emulsified asphalt materials and mineral aggregate usually prepared in a conventional hot-mix plant or drum mixer at a temperature of not more than 260°F (127°C). It is spread and compacted at the job site at a temperature above 200°F (93°C).

Initial Treatment: The first asphalt surfacing on an unpaved road or street.

Multiple Surface Treatment: Two or more surface treatments placed one on the other. The aggregate maximum size of each successive treatment is usually one-half that of the previous one, and the total thickness is about the same as the nominal maximum size aggregate particles of the first course. Or, a multiple surface treatment may be a series of single treatments that produce a pavement course up to 1 inch (2.5cm) or more. A multiple surface treatment is a denser wearing and waterproofing course than a single surface treatment, and it adds some strength.

Pavement Base and Surface: The lower or underlying pavement course atop the sub-base or subgrade and the top layers or wearing course.

Prime Coat: An application of low viscosity fluid asphalt to an absorbent surface. It is used to prepare an untreated base for an asphalt surface. The prime penetrates into the base and plugs the voids, hardens the top of the base and helps bind it to the overlying asphalt course.

Road Oiling: Similar to dust laying except fluid cut back asphalts are used and usually it is done as a part of planned build-up of low-cost road surfaces over several years. Each application of asphalt may be mechanically mixed with the material being treated or allowed to penetrate.

Seal Coat: A thin surface treatment used to improve the texture of and waterproof an asphalt surface. Depending on the purpose, seal coats may or may not be covered with aggregate. The main types of seal coats are aggregate seals, fog seals, emulsion slurry seals, and sand seals.

Surface Treatment: A thin application of Asphalt/Aggregate, Premixed Asphalt-Aggregate, or Asphalt to an existing road or street surface for the purpose of sealing the surface, and/or improving surface properties, may vary in thickness from a very thin layer of asphalt up to about 1 inch of asphalt and aggregate.

Tack Coat: A very light application of liquid asphalt, usually asphalt emulsion diluted with water. It is used to ensure a bond between the surface being paved and the overlying course.

Hot Plantmix Surface Treatment: A thin layer, 1/2 to 1 inch thick, of hot asphalt concrete or sand asphalt constructed to seal the surface and to do minor leveling of the surface.

Cold Plantmix Surface Treatment: A thin layer of cold plantmix similiar to hot mix surface treatment constructed for the same reasons.

APPENDIX B

SPECIFICATIONS

Emulsified Asphalt and Primer
- Kentucky DOH - Standard Specifications for Roads and Bridges
  - Emulsified Asphalts - Section 806.07
  - Primer - Section 806.08
  - Cut Back Asphalt Primer - Section 806.09
- ASTM
  - Emulsified Asphalts (Anionic) D-977
  - Emulsified Asphalts (Cationic) D-2397
  - Cutback Asphalt (Medium Curing) D-2027

Aggregate for Surface Treatments
- Kentucky DOH - Standard Specifications for Roads and Bridges
  - Coarse Aggregate - Section 805
  - Fine Aggregate - Section 804.01,.02,.03,.04.02
- ASTM
  - Coarse Aggregate D-448
  - Standard Aggregate Sizes

Surface Treatments
- Kentucky DOH - Standard Specifications for Roads and Bridges
  - Bituminous Seal Coat - Section 406
  - Bituminous Prime & Tack Coats - Section 407
  - Sand Asphalt Surface - Section 404
  - Bituminous Plant Mixed Pavements - Section 401
- ASTM
  - Materials, Quantities, and Practice - D1369
  - Slurry Seals - D3910

The ASTM specifications not included in this manual are for reference only and may or may not apply to local needs.

Standard Specifications for Roads and Bridges are available from the Kentucky Department of Highways.

TABLE B1

SPECIAL NOTE FOR
POLYMER-ASPHALT EMULSIONS FOR SEAL COAT APPLICATIONS

These products are designed for surface treatment by the technique specified in Section 406 of the Kentucky Standard Specifications for Road and Bridge Construction, and shall be furnished when specified elsewhere in the contract.

REQUIREMENTS

Test	CRS-2S or RS-2S Min.	CRS-2S or RS-2S Max.	AE-90S Min.	AE-90S Max.
1. Viscosity, SSF, @122 F. (AASHTO-T59)	175	450	50+	
2. Storage Stability Test, 24 hrs., % (AASHTO-T59)	---	1		1
3. Sieve Test, 20 mesh, % (AASHTO-T59)		0.1		0.1
4. Distillation: (AASHTO-T59) Oil Distillate by Vol. of Emulsion, %		3		3.0
Residue from Distillation, %:	65		65	
Test on Residue from Evaporation or Distillation: (AASHTO T59)				
5. Penetration, 77 F., 100, 5 sec. (AASHTO T49)	90	150	90	150
6. Ductility, 77 F, cm. (AASHTO T51)	50+		50+	
7. Ductility, 34 ± 1 F. (AASHTO T51)	15+		15+	
*8. Ductility, 34 ± 1 F. (AASHTO T51)	55+		55+	
9. Solubility in Trichloroethylene, % (AASHTO T44)	97.5			
10. Demulsibility, 0.02N CaCl, % (AASHTO T59), Anionic Emulsion	40+		40+	
11. Demulsibility, 35 ml., 0.8% Sodium Dioctyl Sulfosuccinate, % (AASHTO T59) Cationic Emulsion	20+			
12. Float Test @ 140 F. sec. (AASHTO T59)			1200+	

*This test is an extension of the routine ductility test. When the specimen is extended 10 cm. the distressed area is severed in the middle by a pair of shears. After one hour at the test temperature, the severed distressed ends are returned to contact and the ductilometer reading is read again. The sample must recover at least 55% of the 10 cm. distance or to a reading of 4.5 or less.

Suppliers of the specified CRS-2S, RS-2S, or AE-90S may be required to perform and certify conformance to the above test requirements prior to shipment of the material.

CRS-2S is intended to be used in seal coat applications where the stone is siliceous, minus no. 200 sieve fines are less than 3%, high skid resistance is desired, and early retention of aggregate is required. RS-2S is intended to be used like CRS-2S except it is to be used with limestone aggregate. AE-90S is to be used with limestone but, due to its slower setting speed, is more tolerant of fines than the other products. Aggregates that are not clearly defined as limestone or siliceous should be evaluated for compatibility with the intended emulsion to assure the best retention of aggreate. Non-compatibility is judged to be failure of an aggregate to adhere to a particular emulsion.

Generally, the quality of the finished product improves as aggregate fines are decreased. Increasing fine material passing a no. 200 sieve always decreases the quality of a seal coat application.

November 11, 1986

Source: Kentucky Department of Highways

TABLE B2

BITUMINOUS MATERIALS
TEMPERATURE DATA

The shipping, storage and use of various bituminous materials requires a variety of temperatures. The chart below is assembled to assist in determining appropriate temperatures. Higher or lower temperatures may be used depending on individual materials (source recommendations), climate conditions, length of storage or variety of use.

Material	Shipping [1] Temperature	Storage [2] Temperature	Mixing Temperature	Spraying Temperature	Remarks
MC-250	100-120°F	60-110°F	100-180°F	100-180°F	Extended storage could be held at low temperatures below 32°F if desired.
MC-800	120-180°F	80-120°F	120-200°F	150-200°F	
RC-800	100-120°F	80-110°F	--------	120-180°F	
SS-1H	60-120°F	60-100°F	60-140°F	60-150°F	
AE-60	60-140°F	60-100°F	60-120°F	60-150°F	
AE-200	130-180°F	60-100°F	100-140°F	100-180°F	
MS-3	130-180°F	60-100°F	100-140°F	100-180°F	
HFMS-2	130-180°F	60-100°F	100-140°F	100-180°F	
CRS-2S	130-180°F	60-100°F	---------	120-180°F	Mixing through McConnaughay Mixers acceptable. Do not plan on storage for longer than 1-4 days. Storage is risky.
RS-2S	130-180°F	60-100°F	---------	120-180°F	
AE-90S	130-180°F	60-100°F	---------	120-180°F	
RS-1	60-120°F	60-100°F	---------	80-140°F	
RS-2	120-160°F	60-100°F	---------	110-160°F	
RS-2C	120-150°F	60-100°F	---------	120-160°F	
HFRS-2					
Primer"L"	60-120°F	60-100°F	60-120°F	60-180°F	Mixing not recommended.

(1) The temperatures listed in this column are probable temperatures at which the materials may be received. Always inform source of desired temperature.

(2) Storage of water-based products such as asphalt emulsions should never be allowed to drop below 40°F. Demulsification begins to occur rapidly below 40°F with emulsions. Never allow asphalt emulsions to exceed 200°F because water boils at 212°F, therefore producing uncontrolled foaming and possible explosions of the tank.

Source: Kentucky Department of Highways

TABLE B3

REQUIREMENTS AND TYPICAL APPLICATIONS FOR CATIONIC EMULSIFIED ASPHALT

D 2397

Type	Rapid-Setting				Medium-Setting				Slow-Setting			
Grade	CRS-1		CRS-2		CMS-2		CMS-2h		CSS-1		CSS-1h	
	min	max	min	max	min	max	min	max	min	max	min	max
Test on emulsions:												
Viscosity, Saybolt Furol at 77°F (25°C), s									20	100	20	100
Viscosity, Saybolt Furol at 122°F (50°C), s	20	100	100	400	50	450	50	450				
Settlement,[a] 5-day, %		5		5		5		5		5		5
Storage stability test,[b] 24-h, %		1		1		1		1		1		1
Classification test[c]	passes		passes									
or												
Demulsibility,[d] 35 ml 0.8 % sodium dioctylsulfosuccinate, %	40		40									
Coating, ability and water resistance:												
Coating, dry aggregate					good		good					
Coating, after spraying					fair		fair					
Coating, wet aggregate					fair		fair					
Coating, after spraying					fair		fair					
Particle charge test	positive		positive		positive		positive		positive		positive	
Sieve test, %		0.10		0.10		0.10		0.10		0.10		0.10
Cement mixing test, %										2.0		2.0
Distillation:												
Oil distillate, by volume of emulsion, %		3		3		12		12				
Residue, %	60		65		65		65		57		57	
Tests on residue from distillation test:												
Penetration, 77°F (25°C), 100 g, 5 s	100	250	100	250	100	250	40	90	100	250	40	90
Ductility, 77°F (25°C), 5 cm/min, cm	40		40		40		40		40		40	
Solubility in trichloroethylene, %	97.5		97.5		97.5		97.5		97.5		97.5	
Typical applications[e]	surface treatment, penetration macadam, sand seal coat, tack coat, mulch		surface treatment, penetration macadam, coarse aggregate seal coat (single and multiple)		cold plant mix, coarse aggregate seal coat (single and multiple), crack treatment, road mix, tack coat, sand seal coat		cold plant mix, hot plant mix, coarse aggregate seal coat (single and multiple), crack treatment, road mix, tack coat		cold plant mix, road mix, slurry seal coat, tack coat, fog seal, dust layer, mulch			

[a] The test requirement for settlement may be waived when the emulsified asphalt is used in less than 5 days time; or the purchaser may require that the settlement test be run from the time the sample is received until the emulsified asphalt is used, if the elapsed time is less than 5 days.

[b] The 24-h storage stability test may be used instead of the 5-day settlement test.

[c] Material failing the classification test will be considered acceptable if it passes the demulsibility test.

[d] The demulsibility test shall be made within 30 days from date of shipment.

[e] These typical applications are for use only as a guide for selecting and using the emulsion for pavement construction and maintenance.

TABLE B4

REQUIREMENTS AND TYPICAL APPLICATIONS FOR EMULSIFIED ASPHALT

D 977

Type	Rapid-Setting				Medium-Setting						Medium-Setting						Slow-Setting			
	RS-1		RS-2		MS-1		MS-2		MS-2h		HFMS-1		HFMS-2		HFMS-2h		SS-1		SS-1h	
Grade	min	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max
Tests on emulsions:																				
Viscosity, Saybolt Furol at 77°F (25°C), s	20	100			20	100	100		100		20	100	100		100		20	100	20	100
Viscosity, Saybolt Furol at 122°F (50°C), s			75	400																
Settlement,[a] 5-day, %		5		5		5		5		5		5		5		5		5		5
Storage stability test,[b] 24-h, %		1		1		1		1		1		1		1		1		1		1
Demulsibility,[c] 35 ml, 0.02 *N* $CaCl_2$, %	60		60																	
Coating ability and water resistance:																				
Coating, dry aggregate					good		good		good		good		good		good					
Coating, after spraying					fair		fair		fair		fair		fair		fair					
Coating, wet aggregate					fair		fair		fair		fair		fair		fair					
Coating, after spraying					fair		fair		fair		fair		fair		fair					
Cement mixing test, %																		2.0		2.0
Sieve test, %		0.10		0.10		0.10		0.10		0.10		0.10		0.10		0.10		0.10		0.10
Residue by distillation, %	55		63		55		65		65		55		65		65		57		57	
Tests on residue from distillation test:																				
Penetration, 77°F (25°C), 100 g, 5 s	100	200	100	200	100	200	100	200	40	90	100	200	100	200	40	90	100	200	40	90
Ductility, 77°F, (25°C), 5 cm/min, cm	40		40		40		40		40		40		40		40		40		40	
Solubility in trichloroethylene, %	97.5		97.5		97.5		97.5		97.5		97.5		97.5		97.5		97.5		97.5	
Float test, 140°F (60°C), s												1200		1200		1200				
Typical applications[d]	surface treatment, penetration macadam, sand seal coat, tack coat, mulch		surface treatment, penetration macadam, coarse aggregate seal coat (single and multiple)		cold plant mix, road mix, sand seal coat, crack treatment, tack coat		cold plant mix, coarse aggregate seal coat (single and multiple), crack treatment, road mix, tack coat, sand seal coat		cold plant mix, hot plant mix, coarse aggregate seal coat (single and multiple), crack treatment, road mix, tack coat		cold plant mix, road mix, sand seal coat, crack treatment, tack coat		cold plant mix, coarse aggregate seal coat (single and multiple), crack treatment road mix, tack coat, and seal		cold plant mix, hot plant mix, coarse aggregate seal coat (single and multiple), crack treatment road mix, tack coat		cold plant mix, road mix, slurry seal coat, tack coat, fog seal, dust layer, mulch			

[a] The test requirement for settlement may be waived when the emulsified asphalt is used in less than 5 days time; or the purchaser may require that the settlement test be run from the time the sample is received until the emulsified asphalt is used, if the elapsed time is less than 5 days.

[b] The 24-h storage stability test may be used instead of the 5-day settlement test.

[c] The demulsibility test shall be made within 30 days from date of shipment.

[d] These typical applications are for use only as a guide for selecting and using the emulsion for pavement construction and maintenance.

TABLE B5

STANDARD SIZE AGGREGATES FOR SURFACE TREATMENTS

Size No.	Nominal Size (Sieves with Square Openings	Amounts Finer Than Each Laboratory Sieve (Square Openings), Weight Percent								
		1-1/2 in.	1 in.	3/4 in.	1/2 in.	3/8 in.	No. 4	No. 8	No. 16	No. 50
5	1 to 1/2 in.	100	90 to 100	20 to 55	0 to 10	0 to 5	--	--	--	--
57	1 in. to No. 4	100	95 to 100	--	25 to 60	--	0 to 10	0 to 5	--	--
6	3/4 to 3/8 in.	--	100	90 to 100	20 to 55	0 to 15	0 to 5	--	--	--
67	3/4 in. to No. 4	--	100	90 to 100	--	20 to 55	0 to 10	0 to 5	--	--
68	3/4 in. to No. 8	--	100	90 to 100	--	30 to 65	5 to 25	0 to 10	0 to 5	--
7	1/2 in. to No. 4	--	--	100	90 to 100	40 to 70	0 to 15	0 to 5	--	--
78	1/2 in. to No. 8	--	--	100	90 to 100	40 to 75	5 to 25	0 to 10	0 to 5	--
8	3/8 in. to No. 8	--	--	--	100	85 to 100	10 to 30	0 to 10	0 to 5	--
9M*	3/8 in. to No. 4	--	--	--	100	75 to 100	0 to 25	0 to 5	--	--

* Kentucky Department of Highways

TABLE B6 GENERAL USES OF EMULSIFIED ASPHALT

NOTE—Only those grades of emulsified asphalt in general use have been indicated herein. It is possible that under certain variations of aggregates, or climatic conditions, or both, additional selections might be appropriate. Where the use of emulsified asphalt for applications other than those listed in the table are contemplated, the emulsion supplier should be consulted.

Type of Construction	ASTM D977 AASHTO M 208								ASTM D2397 AASHTO M 140					
	RS-1	RS-2	MS-1, HFMS-1	MS-2, HFMS-2	MS-2h, HFMS-2h	HFMS-2s	SS-1	SS-1h	CRS-1	CRS-2	CMS-2	CMS-2h	CSS-1	CSS-1h
Asphalt-aggregate mixtures:														
For pavement bases and surfaces:														
Plant mix (hot)	...	...	...	...	X[A]	...	...	...	...	...	...	...	...	...
Plant mix (cold)														
Open-graded aggregate	...	...	...	X	X	...	...	...	...	...	X	X	...	...
Dense-graded aggregate	...	...	...	...	...	X	X	X	...	...	...	...	X	X
Sand	...	...	...	...	...	X	X	X	...	...	...	...	X	X
Mixed-in-place:														
Open-graded aggregate	...	...	...	X	X	...	...	...	...	...	X	X	...	...
Dense-graded aggregate	...	...	...	...	...	X	X	X	...	...	...	...	X	X
Sand	...	...	...	...	...	X	X	X	...	...	...	...	X	X
Sandy soil	...	...	...	...	...	X	X	X	...	...	...	...	X	X
Slurry seal	...	...	...	...	...	X	X	X	...	...	...	...	X	X
Asphalt-aggregate applications:														
Treatments and seals:														
Single surface treatment (Chip Seal)	X	X	...	...	...	...	...	...	X	X	...	...	...	...
Multiple surface treatment	X	X	...	...	...	...	...	...	X	X	...	...	...	...
Sand seal	X	X	X	...	...	...	...	...	X	X	...	...	...	...
Asphalt applications:														
Fog seal	...	...	X[B]	...	...	...	X[C]	X[C]	...	...	...	...	X[C]	X[C]
Prime coat-penetrable surface	...	...	...	X[D]	...	...	X[D]	X[D]	...	...	...	...	X[D]	X[D]
Tack coat	...	...	X[B]	...	...	...	X[C]	X[C]	...	...	...	...	X[C]	X[C]
Dust binder	...	...	...	...	...	...	X[C]	X[C]	...	...	...	...	X[C]	X[C]
Mulch treatment	...	...	...	...	...	...	X[C]	X[C]	...	...	...	...	X[C]	X[C]
Crack filler	...	...	...	...	...	...	X	X	...	...	...	...	X	X
Maintenance mix:														
Immediate use	...	...	...	...	...	X	X	X	...	...	...	...	X	X

[A] Grades of emulsion other than FHMS-2h may be used where experience has shown that they give satisfactory performance.
[B] Diluted with water by the manufacturer.
[C] Diluted with water.
[D] Mixed-in prime only.

Courtesy The Asphalt Institute

APPENDIX C

SPECIFIED TESTS FOR EMULSIFIED ASPHALTS

Most local road or street agencies do not have testing laboratories for materials. For this reason, emulsified asphalts of any type or grade are usually accepted on the basis of certification by the supplier. This certification states that all requirements of the specifications have been met and provides values of test results for each test specified.

The following does not deal with procedures for testing. It describes what the test means and why it is used. This will provide a better understanding of these important materials.

Asphalt emulsions are mixtures of asphalt cement and water. During storage or construction, the user works with the total emulsion. After construction, the water is lost by evaporation and the asphalt cement remains in the pavement. For these reasons, a series of tests is run on the emulsion and a second series on the asphalt cement.

TESTS ON THE TOTAL ASPHALT EMULSION

Residue by Distillation

This is a distillation test that removes the water from the emulsion leaving asphalt cement. The minimum percent of asphalt cement in each type and grade is specified. The residue from this test, asphalt cement, is retained for further testing.

Oil Distillate

The percentage of oil in the emulsion also is determined during the distillation test. Many emulsions contain no oil. Some include a small percentage to improve coating ability of the emulsion.

Particle Change

This test identifies the emulsion as anionic or cationic. The test is only specified for cationic grade of emulsion. These must show a positive charge.

Viscosity

These are very important tests for controlling the emulsion grade and are equally important in their use. They measure the fluidity of the emulsion in the application temperatures range. It is important that viscosity is well within the specified range and remains consistent throughout the work. Variable viscosity will cause variations in the amount of liquid the distributor will spray for any given setting.

Demulsibility

This test is run on both anionic and cationic rapid setting emulsions. It indicates the relative rate that asphalt cement particles separate from water in the emulsion, the break. In Rapid Setting grades it is essential that separation occur very quickly after the emulsion is applied. Test limits are specified to assure the break will occur rapidly, as it should.

Settlement

This tests the stability of the emulsion when stored. If the emulsion is stable, as specified, the amount of asphalt in the emulsion will vary little in the upper or lower portion of a storage tank for a few days. The settlement test determines whether stability requirements have been met. This test applies to all emulsions.

Cement Mixing

This test is run on both anionic and cationic, slow setting grades of emulsion. It is a stability test for materials that are intended to be resistant to breaking.

Sieve Test

The sieve test is used to assure that asphalt droplets in the emulsion have not joined together to form large globules. If this has occurred, pumping equipment may become clogged. Further, proper aggregate coating cannot be achieved.

Miscibility With Water

This test is to determine if slow setting or medium setting emulsions can be mixed with water. Slow setting emulsions often must be diluted with water for use. Medium setting emulsions also may be mixed with excess water present. The test is not run on rapid setting emulsions.

Coating Tests

These tests are intended to assure that the emulsion will coat moist aggregate and that the coating will remain in the presence of additional water. The emulsion and aggregate to be used on the job should be used for testing, or a standard aggregate may be used. These tests are used for medium setting grades only.

Storage Stability

This test is similar in purpose to the settlement test. It is a measure of the difference in asphalt percentage at the top and bottom of a sample. This test may be used instead of the settlement test.

TESTS ON ASPHALT CEMENT

Penetration

This is a consistency test that measures the hardness of asphalt cement at 77^{0}F. It assures that the proper grade of asphalt cement was used in manufacturing the emulsion.

Float Test

This test is used only for high float type emulsions. It measures the resistance to flow of asphalt cement at 140^{0}F.

Ductility Test

The ductility test is used to assure that the asphalt cement can elongate without breaking. It guards against brittle asphalts being used.

Solubility Test

This test measures the amount to pure asphalt in the asphalt cement.

STORING, HANDLING, AND SAMPLING ASPHALT EMULSIONS

GENERAL

The storage and handling of asphalt emulsions require precaution beyond that used for other types of asphalt materials. Improper handling or storage of the emulsion, or both, may cause premature breaking, thereby making it useless. The Asphalt Institute, in recognition of these necessary precautions, has issued a Construction Leaflet, *Storing and Handling of Emulsified Asphalts* (CL-21), outlining some of the safeguards that must be followed. Failure to follow even a single one of them may cause the material to be unsatisfactory at the time of use. Careful study of each item is therefore suggested. Sticking to these simple rules will save time and money by having the material ready for use when needed. The safeguards listed in the Asphalt Institute leaflet are repeated below to help those who have had little or no experience with asphalt emulsions. However, it is not intended to give the impression that asphalt emulsions are so delicate as to limit their field use. The use of almost any other material would have a long list of admonitions for the uninitiated.

STORING ASPHALT EMULSIONS

Emulsified asphalt, being a dispersion of fine droplets of asphalt cement in water, has both the advantages and disadvantages of the carrier medium, water. When storing emulsified asphalts:

DO store as you would fluid water—between 50° F (10° C) and 185° F (85° C), depending on the use.

DO use hot water as the heating medium for storage tanks with heating coils. Low pressure or waste steam also may be used, with temperature controlled on the coil surface to not more than 185° F (85° C).

DO store at the temperature specified for the particular grade. For spray applications, the emulsions are stored at higher temperatures than for mixing with aggregate. For example, the higher viscosity rapid-set spray grades are stored at 125° F to 185° F (50° C to 85° C) since they are usually applied in this temperature range. The lower viscosity grades are stored at lower temperatures. Table III-1 shows the normal storage temperature ranges. Store the mixing grades at the lower end of the temperature ranges as shown in Table III-1.

DO NOT permit the emulsified asphalt to be heated above 185° F (85° C). Elevated temperatures evaporate the water, resulting in an increase in viscosity and an asphalt layer in the tank. The materials can no longer be used as intended and it will be difficult to empty the tank.

DO NOT let the emulsion freeze. This breaks the emulsion, separating the asphalt from the water. The result will be two layers in the tank, neither suited for the intended use, and the tank will be difficult to clean.

DO NOT allow the temperature of the heating surface to exceed 205° F (96° C). This will cause premature breakdown of the emulsion on the heating surface.

DO NOT use forced air to agitate the emulsion. It may cause the emulsion to break.

TABLE D1 **STORAGE TEMPERATURES FOR EMULSIFIED ASPHALTS**

Grade	Temperature, °F (°C)	
	Minimum	Maximum
RS-1	70° (20°)	140° (60°)
RS-2, CRS-1, CRS-2	125° (50°)	185° (85°)
SS-1, SS-1h, CSS-1, CSS-1h, MS-1, HFMS-1	50° (10°)	140° (60°)
CMS-2, CMS-2h, MS-2, MS-2h, HFMS-2, HFMS-2h	125° (50°)	185° (85°)

STORAGE FACILITIES

For protection from freezing and best utilization of heat, storage tanks should be insulated. A skin of asphalt can form on the surface of emulsions when exposed to air. It is best, therefore, to use tall, vertical tanks as they expose the least amount of surface area to the air. Most fixed storage tanks are vertical but horizontal tanks are often used for short-term field storage. Skinning can be reduced by keeping horizontal tanks full to minimize the area exposed to air.

Side-entering propellers located about three feet (one metre) up from the tank bottom may be used to prevent surface skin formation. Large diameter, slow-turning propellers are best and should be used to roll the material over. Avoid overmixing. Secondly, tanks may be circulated top to bottom with a pump. Avoid over-pumping. In tanks not equipped with propellers, or a circulating system, a very light film of kerosene or oil on the surface can reduce skin formation. Emulsions that are rolled or circulated generally do not require a layer of kerosene or oil on the surface. Cathodic protection should be provided to avoid possible corrosion of tank walls and heating coils.

HANDLING EMULSIFIED ASPHALTS

DO when heating emulsified asphalt agitate it to eliminate or reduce skin formation.

DO protect pumps, valves, and lines from freezing in winter. Drain pumps or fill them with anti-freeze according to the manufacturer's recommendations.

DO blow out lines and leave drain plugs open when they are not in service.

DO use pumps with proper clearances for handling emulsified asphalt. Tightly fitting pumps can cause binding and seizing.

DO use a mild heating method to apply heat to the pump packing or casing to free a seized pump. Discourage the use of propane torches.

DO warm the pump to about 150° F (65° C) to ease start-up.

DO when a pump is to be out of service for even a short period of time, fill it with No. 1 fuel oil to ensure a free start-up.

DO when diluting grades of emulsified asphalt, check the compatibility of the water with the emulsion.

DO if possible, use warm water for diluting and always add the water slowly to the emulsion (not the emulsion to the water).

DO avoid repeated pumping and recycling, if possible, as the viscosity may drop and air may become entrained, causing the emulsion to be unstable.

DO guard against mixing different classes, types, and grades of emulsified asphalt in storage tanks, transports, and distributors. For example, if cationic and anionic emulsified asphalts are mixed, the blend will break and separate into water and coagulated asphalt that will be difficult to remove. Because it is hard to determine visually the difference between various emulsified asphalts, always make a trial blend of the newly-delivered emulsion and the stored emulsion before pumping off. Check the trial blend for compatibility.

DO place inlet pipes and return lines at the bottom of tanks to prevent foaming.

DO pump from the bottom of the tank to minimize contamination from skinning that may have formed.

DO remember that emulsions with the same grade designation can be very different chemically and in performance.

DO haul emulsion in truck transports with baffle plates to prevent sloshing.

DO mix by circulation, or otherwise, emulsions that have been in prolonged storage.

DO NOT use tight-fitting pumps for pumping emulsified asphalt; they may "freeze."

DO NOT apply severe heat to pump packing glands or pump casings. The pump may be damaged and the asphalt may become even harder.

DO NOT dilute rapid-setting grades of emulsified asphalt with water. Medium and slow setting grades may be diluted, but always add water slowly to the asphalt emulsion. Never add the asphalt emulsion to a tank of water when diluting.

DO NOT recirculate emulsified asphalts for too many cycles. They tend to lose viscosity when subjected to pumping. Also, air bubbles may become entrained which would render the emulsion unstable.

DO NOT load emulsified asphalt into storage tanks, tank cars, tank transports, or distributors containing remains of incompatible materials. See Tables D2 and D3.

TABLE D2

GUIDE FOR CONDITION OF EMPTIED TANKS BEFORE LOADING EMULSIFIED ASPHALTS

	LAST PRODUCT IN TANK					
PRODUCT TO BE LOADED	Asphalt Cement (includes Industrial Asphalt)	Cutback Asphalt	Cationic Emulsion	Anionic Emulsion	Crude petroleum and residual fuel oils	Any product not listed above
Cationic Emulsion	Empty to no Measurable Quantity	Empty to no Measurable Quantity	OK to load	Empty to no Measurable Quantity	Empty to no Measurable Quantity	Tank must be cleaned
Anionic Emulsion	Empty to no Measurable Quantity	Empty to no Measurable Quantity	Empty to no Measurable Quantity	OK to load	Empty to no Measurable Quantity	Tank must be cleaned

NOTE: All tanks to be emptied to 0.5 percent or less of capacity. Pump section, unloading line, and all piping must be drained.

TABLE D3

POSSIBLE CAUSES OF CONTAMINATION OF ASPHALT MATERIAL OR SAMPLES AND SUGGESTED PRECAUTIONS

HAULERS AND HAULING VEHICLES

Field observations and studies of test results have indicated that contamination of materials during transportation often occurs.

Possible Causes	*Precautions*
(a) Previous load not compatible with material being loaded.	Examine the log of loads hauled or check with the supplier to determine if previous material hauled is detrimental. If it is, make sure vehicle tanks, unloading lines, and pump are properly cleaned and drained before being presented for loading. Provide a ramp at the unloading point at the plant that will ensure complete drainage of vehicle tank while material is still fluid.
(b) Remains of diesel oil or solvents used for cleaning and flushing of tanks, lines, and pump.	When this is necessary, make sure all solvents are completely drained.
(c) Flushing of solvents into receiving storage tank or equipment tanks.	Do not allow even small amounts to flush into storage tank as entire contents may be contaminated

(Continued on next page)

TABLE D3 **(con't.)**

MIX PLANT STORAGE TANK AND EQUIPMENT

Many investigations and test results point to mix plant storage tanks and associated equipment as the source of contamination.

Possible Causes	*Precautions*
(a) Previous material left over in tank when changing to another material.	Any material allowed to remain must be compatible with new material; and the amount remaining in the tank must be insufficient to cause new material to become out-of-specification. If in doubt, check with your supplier. To be on the safe side, tank should be drained or cleaned prior to using tank for each different type or grade of asphalt. Be sure discharge line connects at low point of storage tank to ensure complete emptying when changing type or grades of asphalt or cleaning tank.
(b) Solvents used to flush hauling vehicle tank discharged into storage tank.	Observe unloading operations, caution driver about flushing cleaning materials into storage tank. If possible, provide place for hauler to discharge cleaning materials.
(c) Flushing of lines and pump between storage tank and hot-plant with solvents and then allowing this material to return to tank.	If necessary to flush lines and pump, suggest providing bypass valves and lines to prevent solvents from returning to tank. A better solution is to provide insulated, heated lines and pump, thereby eliminating the necessity of flushing.
(d) Cleaning of distributor tank, pump, spray bar, and nozzles with solvents.	Be sure all possible cleaning material is drained off or removed prior to loading. Do not take sample from nozzle until sufficient material has been discharged to guard against taking a contaminated sample.
(e) Dilutions from hot oil heating systems.	Check reservoir on hot oil heating system. If oil level is low, or oil has been added, check system for leakage into the asphalt supply.

NON-REPRESENTATIVE OR CONTAMINATED SAMPLE

Test results are greatly dependent upon proper sampling techniques. Extra care, on the part of the sampler, to obtain samples that are truly representative of the material being sampled will do much to eliminate the possibility of erroneous test results by reason of improper sampling. Make sure samples are taken only by those authorized persons who are trained in sampling procedures.

Possible Causes	*Precautions*
(a) Contaminated sampling device (commonly called a "sample thief").	If sampling device (of type described in AASHTO T 40 or ASTM D 140) is cleaned with diesel oil or solvent, make sure that it is thoroughly drained and then rinsed out several times with material being sampled prior to taking sample.
(b) Samples taken with sampling device from top of tank where, under certain conditions, contaminants can collect on the surface.	In taking a sample from the top of a tank lower sampling device below the extreme top before opening. Note: This sample may come from the top one-third of the tank.

(Continued on next page)

TABLE D3 **(Con't.)**

Possible Causes	*Precautions*
(c) Contaminated sample container.	Use only new clean containers. Never wash or rinse a sample container with solvent. Glass or polyethylene containers should be used.
(d) Sample contaminated after taking.	**DO NOT** submerge container in solvent or even wipe outside of container with solvent-saturated rag. If necessary to clean spilled material from outside of container, use a clean dry rag. Make sure container lid is tightly sealed prior to storage or shipment. Ship to testing laboratory promptly.
(e) Samples taken from spigot in lines between storage tank and hot-plant.	If sampling spigot is in suction line between tank and pump, this necessitates stopping pump prior to taking sample. Samples thus taken are by gravity and only representative of material localized in the pipe area of the spigot. Rather, the spigot should be in lines between pump and return line discharge, thereby allowing slow withdrawal of material during circulation. **DO NOT** take sample while hauling vehicle is pumping into storage tank. **DO NOT** take sample without allowing sufficient time for circulation and thorough mixing of material. **DO** drain off sufficient material through spigot prior to taking sample to ensure removal of any contaminant lodged in spigot. **DO** take sample slowly during circulation to be more representative of material being used.
(f) Samples taken from unloading line of hauling vehicle.	Drain off sufficient material through spigot prior to taking sample to ensure removal of any contaminant lodged there. Sample should be taken after one-third and not more than two-thirds of the load has been removed. Take sample slowly to be sure it is representative of the material being used.

Courtesy The Asphalt Institute

APPENDIX E

CALIBRATION OF SURFACE TREATMENT OF EQUIPMENT

Good surface treatment work is dependant on accurately applying asphalt and aggregate at the intended rates. This involves two pieces of equipment, the asphalt distributor and the aggregate spreader. Both these items should be calibrated to assure asphalt and aggregate are applied at the rates intended.

Calibration consists of testing the equipment at several settings and measuring the amount of material actually being applied. Manufacturers usually supply charts or tables that show application rates for various settings and materials. This information is generally very nearly correct but should be checked by calibration for your particular equipment and materials. Usually the manufacturer also supplies a detailed calibration procedure in the Operators Manual. The following discusses the general requirements and some procedures that may be useful. It further discusses procedures that should be used to continually check application rates during construction.

ASPHALT DISTRIBUTOR CALIBRATION

Rate of Application

The rate at which asphalt is applied depends upon the quantity of asphalt delivered by the pump to the spray bar and the speed of forward movement. The amount of asphalt delivered per minute may, depending on the distributor used, be a function of either the pump pressures or the pump speed (RPM). Calibration should be run at either a series of pump pressures or pump speeds (RPM) that will produce a good fan at each nozzle. At each of these settings, the distributor is tested at a series of speeds and the actual amount of asphalt applied per square yard is measured.

The American Society for Testing and Materials (ASTM) provides a Standard Practice for Calibration of Bituminous Distributors in D2995-84. This is not a complete calibration procedure in that it provides a procedure for evaluating the rate of application, transversely or longitudinally, for a single pump setting and forward speed. If the procedure is repeated at several settings of pumps and/or forward speed, complete calibration can be done. This procedure also evaluates the variation in rates of delivery transversely across the full width of spread. Most frequently, this procedure is run at a single pump setting and three or more forward speeds that encompass the anticipated speeds for the planned work.

A second, simpler, calibration procedure that is frequently used evaluates application rate in the central portion of the spread only. In this procedure, a square metal tray, measuring one yard in each dimension, is constructed. Heavy paper, such as building paper, is carefully cut to fit into the tray. The paper is weighed prior to placing in tray. The tray is then placed on the roadway in a position that will be between the distributor wheels. The distributor pump is set to provide a good, uniform spray fan. A forward speed is selected that should deliver the desired rate of application. After the distributor has passed, the paper and asphalt coating is removed from the tray and weighed. The weight of asphalt applied is determined by subtracting the original weight of the paper. This weight is then divided by the weight of one gallon of asphalt to determine the rate of application in gallons per square yards. This procedure may be repeated at other forward speeds to include the range of rates that may be needed for the types of surface treatments the agency expects to use.

Distributor Tank Capacity

It is necessary to know the quantity of asphalt in the distributor at any given time. Some distributors have float type gauges for measuring quantity. All have Dip Sticks which may be used for this purpose. Usually either method will measure tank contents to the nearest twenty-five to fifty gallons. The tank can be calibrated during filling to provide more accurate measurements of contents.

Start with the tank empty. Pump asphalt into tank through a calibrated metering pump or on an accurate truck scale. This can best be done at your emulsion suppliers terminal. Load tank in increments each representing about one tenth the tank capacity. Measure each increment and convert the volume or weight to the standard 60^{0}F temperature by use of temperature-volume corrections. Use the dip stick to measure the volume in the tank at each increment. Record, at each increment, the actual standard volume pumped, in gallons, and the exact reading on the dip stick, in inches. When quantities are determined for all increments, prepare a graph by plotting the gallons measured for each increment against the depths, in inches, of emulsion in the tank. Connect these points with a smooth curved line. Using this curve, the gallons in the tank at any depth can be more accurately determined. An example graph prepared by the Asphalt Institute is attached.

Odometer Calibration

The odometer usually consists of a small wheel that rolls along the surface as the distributor advances and a recording mechanism that records distance and rate of movement. Accuracy of the distance and rate readings should be checked periodically.

This is done by measuring and marking some known distance along a straight section of road. Usually a distance of 500 to 600 feet is adequate. Measure the exact distance with a tape and mark the beginning and end locations so they can be easily seen from the distributors cab. Set the odometer wheel at the starting point and zero the meter or record reading. Use a stop watch to measure time of the run in seconds. Start distributor forward movement and accelerate quickly to the desired speed. Start stop-watch when distributor starts. Stop distributor and watch at end marker. Check meter for distance traveled. Convert time traveled to feet per minute (FPM) or miles per hour (MPH) to determine speed as follows.

$$FPM = 60 \frac{(\text{DISTANCE TRAVELED})}{(\text{SECONDS TRAVELED})}$$

$$MPH = 0.6818 \frac{(\text{DISTANCE TRAVELED})}{(\text{SECONDS TRAVELED})}$$

Make at least three runs at any selected speed. Compare the average measured distance and speed to the odometer readings. If they closely agree, the equipment is reliable and calibration is discontinued. If they do not agree, repeat tests at several other speeds and distances. Prepare two graphs by plotting the measured distances and speeds against the odometer distances and speeds. Use the graphs to determine the corrected odometer settings to be used during construction.

Checking the Spread by Total Emulsion Used

The actual emulsion application rate can be and should be checked several times daily during construction. This assures that the intended application rate is being closely met or provides a means of adjusting the actual rate to equal the intended rate. Such checking does not interrupt the normal progress of work.

Use the dip stick to accurately measure the quantity of emulsion in the distributor before the run is started. Measure this quantity again at the end of the run. The difference between the two measurements is the number of gallons applied. Determine the width of application. Determine the distance traveled and the speed of forward movement from the odometer. The actual rate of emulsion applied, gallons per square yard, is found as follows:

$$\text{Gal./sq. yd.} = 9 \frac{(\text{Gallons of Emulsion Used})}{(\text{Width of Spread X Length of Spread})}$$

If the application rate differs 10 percent or more from the intended rate, speed of the distributor should be adjusted to provide the correct application rate. The corrected speed is found as follows:

$$\text{Corrected Speed} = \text{Odometer Speed} \frac{(\text{Actual Application Rate})}{(\text{Intended Application Rate})}$$

Use the corrected speed for the next spray run and check the actual application rate as above described. This procedure can be used to assure that the intended quantity of emulsion is consistently applied.

AGGREGATE FEEDER CALIBRATION

Accurate application of aggregate at the intended rate is very important. The quantity of aggregate spread depends upon the gate opening on the spreader and the speed of spreader movement. When calibrating spreaders, it is very important that the actual stone to be used in the intended work also is used for calibration.

Vane type spreaders cannot be calibrated and aggregate application rate must be enough to provide coverage. The truck driver must attempt to get good coverage without leaving a great deal of excess. This is rarely accomplished.

Tailgate spreader boxes have adjustable gates that permit the truck driver to adjust the gate opening to provide free aggregate flow. By adjusting truck speed, the rate of application can be adjusted. Calibration of this type of spreader is, at best, approximate.

Spreader boxes pushed by the aggregate truck have a distribution bar that is connected to the wheels supporting the box. This provides some adjustment of aggregate quantity being spread if truck speed varies. These boxes also have adjustable gates to accommodate various sizes of aggregate and to adjust the amount being spread. This type of equipment can be calibrated for a particular aggregate but a high degree of accuracy should not be expected.

Self propelled aggregate spreaders can be calibrated with reasonable accuracy for any particular aggregate. This should always be done to assure that the intended rate is being met without undesirable excess.

Calibration Procedure

Calibration should be run at spreader speeds that are essentially equal to the operating speed of the distributor. It is always desired to apply cover aggregate as quickly as possible after the asphalt is applied. It is then necessary to calibrate the spreader at gate openings and forward speeds that meet this need.

For the aggregate to be used on the job, find a gate setting that will permit free flow. Start with this gate setting and determine the rate of application at several speeds near the anticipated distributor speed. Reset gate to a larger opening and repeat. Continue with larger gate openings until the rate of application, within the above noted speed range, is in excess of the aggregate rate desired.

Determine the actual application rate for each run by use of a one square yard pan as described for distributor calibration. Place the pan on the roadway in a location that will be near the center of the spread. After the spreader has passed, weigh the material in the pan. This weight is the application rate in pounds per square yard. Accuracy will be improved by repeating this procedure three times, or more, at each gate setting and speed. If a metal pan of the noted size is not available, a piece of strong canvas or building paper, cut to exactly one square yard, may be used.

Checking the Spread by Total Aggregate Weight

As a means of construction control, the actual aggregate application rate should be checked several times during the project. This can be done with the procedure discussed above or may be calculated from the net weight of aggregate in any truck. This weight will be shown on the weight ticket for each truck.

To calculate the application rates, determine the width and length of spread, in feet, for the particular truck as well as the net aggregate weight in pounds. With this information, the application rate is calculated as follows:

$$\text{Application Rate - lb./sq. yd.} = 9\,\frac{\text{(Weight of Aggregate (lb.)}}{\text{(Spread Length (ft.) X Spread Width (ft.))}}$$

This type check is an important construction control test that can be conducted without interruption of the work. It not only verifies the application rate of aggregate but also provides a means of accounting for all aggregate used on the job.

APPENDIX F

USEFUL TIPS ON SINGLE SURFACE TREATMENT DESIGN AND CONSTRUCTION

The Kentucky Department of Transportation specifies and constructs many surface treatments. To assist their personnel, the Division of Materials has prepared an advisory that offers useful design procedures and construction methods intended to produce safer and more effective results. This advisory, prepared by Ed Minter of the Division of Materials, follows.

CHIP SEAL

A chip seal is often the most cost effective method of extending the life of a roadway. There are some important steps to take in constructing a good chip seal surface. Assuming the money to do the job and that chip sealing is the method agreed upon; let's start with a step-by-step process for doing a good chip seal.

Step 1. Notify the public in advance that the roadway is going to be chip sealed. A newspaper article published several times during the preceding two weeks should give adequate notice. The article should caution the public to adhere to posted speed limits, take detours that are posted and refrain from passing other vehicles through the construction site. There will be loose aggregate on the roadway for a time and the public should be warned in the article.

Step 2. Proper signing should be provided for the project area. Advance construction signs should be placed on both ends of the project warning of the distance to the construction site and of the posted speed limits. Lane closures should be properly posted. Sign details may be obtained from various offices in the Department of Transportation.

Step 3. Choose an Asphalt Emulsion product that will give good performance. The new polymerized emulsion products are superior to the non-polymerized products used in the past such as RS-2 or CRS-2. Their improved performance warrants the extra expense in most all situations. At present, there are three products that could be used. There are two anionic emulsions, RS-2S and AE-90S, and one cationic emulsion, CRS-2S. Each one performs best in a specific way. The CRS-2S product has proven to be the most versatile. The product chosen should be compatible with the stone chosen for the job.

Step 4. Choose an asphalt emulsion application rate that is best for the roadway and stone size. Generally, a rate that is effective will fall between .20 gallons per square yard and .55 gallons per square yard. The table below will give a starting value.

Stone Size	Rate of Emulsion per Square Yard
Ky. No. 11	.20 - .25
Ky. No. 8	.25 - .35
Ky. No. 9M	.30 - .45
Ky. No. 57	.40 - .55

The surface that is to be chipped will help to further define the emulsion rate of application. If the surface is smooth and rich in asphalt the rate selected should be on the low side of the values above. If the surface is badly cracked, raveled and depleted of asphalt then the value selected should be closer to the high side of the values listed above. If the surface is to be left for an indefinite period then favor the low side. If it is to be covered with hot mix in the near future decide on a value closer to the high value.

Step 5. Decide on an aggregate application rate. A very simple method can be used to determine how many pounds of aggregate the emulsion application will accept. Obtain a sample of the emulsion and stone that you intend to use. For simplicity, obtain a flat pan or lid with a lip, such as a gallon flat can lid, to use. A can lid can be disposed of at no great loss. You also will need a balance that is accurate to the nearest gram. Measure the dimensions of the lid surface to be coated with emulsion. Find the area by the formula $A = 1/4 \pi D^2$. The following example should help define the method.

EXAMPLE:

1. Find area of lid surface

$A = 1/4 \pi D^2$

D = diameter of the lid in inches

D = 5.625 inches

π = 3.14 (constant)

$A = 1/4 \times 3.14 \times 5.625 \times 5.625$

A = 24.838 square inches

2. Find out what part of a square yard the can lid represents.

1 square yard = 36" X 36" or 1296 a square yard.

Now divide 1296 by 24.8 to determine what part of a square yard the can lid is. The can lid represents 1/52.3 parts of a square yard.

3. Convert the intended application rate to grams of emulsion for application to the can lid. You will need the weight per gallon of the emulsion to do this. It can usually be found on the manufacturers weight ticket. Generally, emulsions weigh about 8.40 pounds per gallon.

Now multiply 8.40 times 454 grams/pound to convert the weight in pounds per gallon to grams per gallon. 8.40 times 454 = 3813.6 grams per gallon. The can lid represents 1/52.3 parts of a square yard. Let's suppose a rate per gallon of .40 gallons per square yard has been chosen. Since one gallon weighs 3813.6 grams then .40 times 3813.6 will tell us how many grams of emulsion to apply to each square yard. The gallon lid being 1/52.3 parts of a square yard will take $\frac{3813.6 \times .40}{52.3} = 29.17$ grams.

4. Apply 29.17 grams of emulsion to the can lid. Record the final weight of the lid and emulsion.

5. Immediately place enough aggregate on the lid to cover the emulsion several stones thick. Wait one hour.

6. Dump off all loose stone.

7. Weigh the can lid, emulsion and stone. Subtract the can lid and emulsion. The weight remaining is the weight in grams that the emulsion will hold on the roadway. Re-convert the grams of aggregate to pounds per square yard.

$$\text{pounds/square yard} = \frac{\text{grams on lid} \times 52.3}{454 \text{ grams/pound}}$$

In an actual calculation 199 grams of stone were retained on the lid.

$$\text{pounds/square yard} = \frac{199 \times 52.3}{454}$$

$$= 22.92 \text{ or } 23 \text{ pounds of aggregate per square yard.}$$

The value determined will tell you how much aggregate is going to be effective. Additional aggregate will be needed in the amount of approximately 7-10% to serve as a floater to keep equipment from picking up the emulsion and stone.

Step 6. Calibrate the emulsion distributor. Generally distributors have charts that define application rates. A check can be made on the distributor by measuring the quantity used over a given distance and calculating the rate per square yard. The distributor speed can be changed to increase or reduce the application rate.

Step 7. Calibrate the aggregate spread rate. Always keep a running total of aggregate that has been used. After the spreader has passed there should be some black showing through the stone.

Step 8. Roll with pneumatic tired rollers as soon as the aggregate is spread. Three passes should be made to adequately seat the chip into the emulsion.

Step 9. After three to four hours, check the emulsion cure. If the emulsion is cured, sweep the excess stone from the pavement surface. Stone that is not imbedded in the emulsion will act as an abrasive and will erode imbedded aggregate from the roadway surface. There are situations where sweeping must wait for 24 hours. All loose stone should be removed as soon as possible to reduce the danger of loose aggregate being thrown by vehicles and to eliminate abrading action caused by loose aggregate.

APPENDIX G

MISCELLANEOUS TABLES

TABLE G1: Temperature-Volume Corrections for Emulsified Asphalts

TABLE G2: Weight per Cubic Foot and per Cubic Yard of Dry Mineral Aggregates of Different Specific Gravity and Various Void Contents

TABLE G3: Linear Measurement Covered by Tank of any Capacity for Various Widths and Rates of Application

TABLE G4: Linear Feet Covered by 1000-Gallon Tank of Emulsified Asphalt for Various Widths and Rates

TABLE G5: Gallons of Emulsified Asphalt Required per 100 Linear Feet: Various Widths and Rates

TABLE G6: Tons of Aggregate Required per Mile for Various Widths and Rates

TABLE G7: Quantities at Depths in Cylindrical Tanks in a Horizontal Position

TABLE G8: Areas per Mile and per 1000 Linear Feet for Various Widths

TABLE G9: Conversion Factors: U.S. Customary to Metric Units

TABLE G10: Cost of Asphalt Binders per Square Yard - Various Rates and Prices per Gallon

Tables G1 through G9 furnished courtesy of The Asphalt Institute.
Table G10 courtesy of Chevron U.S.A.

TABLE G1 TEMPERATURE-VOLUME CORRECTIONS FOR EMULSIFIED ASPHALTS

°C[t]	°F	M*	°C[t]	°F	M*	°C[t]	°F	M*
10.0	50	1.00250	35.0	95	0.99125	60.0	140	0.98000
10.6	51	1.00225	35.6	96	0.99100	60.6	141	0.97975
11.1	52	1.00200	36.1	97	0.99075	61.1	142	0.97950
11.7	53	1.00175	36.7	98	0.99050	61.7	143	0.97925
12.2	54	1.00150	37.2	99	0.99025	62.2	144	0.97900
12.8	55	1.00125	37.8	100	0.99000	62.8	145	0.97875
13.3	56	1.00100	38.3	101	0.98975	63.3	146	0.97850
13.9	57	1.00075	38.9	102	0.98950	63.9	147	0.97825
14.4	58	1.00050	39.4	103	0.98925	64.4	148	0.97800
15.0	59	1.00025	40.0	104	0.98900	65.0	149	0.97775
15.6	60	1.00000	40.6	105	0.98875	65.6	150	0.97750
16.1	61	0.99975	41.1	106	0.98850	66.1	151	0.97725
16.7	62	0.99950	41.7	107	0.98825	66.7	152	0.97700
17.2	63	0.99925	42.2	108	0.98800	67.2	153	0.97675
17.8	64	0.99900	42.8	109	0.98775	67.8	154	0.97650
18.3	65	0.99875	43.3	110	0.98750	68.3	155	0.97625
18.9	66	0.99850	43.9	111	0.98725	68.9	156	0.97600
19.4	67	0.99825	44.4	112	0.98700	69.4	157	0.97575
20.0	68	0.99800	45.0	113	0.98675	70.0	158	0.97550
20.6	69	0.99775	45.6	114	0.98650	70.6	159	0.97525
21.1	70	0.99750	46.1	115	0.98625	71.1	160	0.97500
21.7	71	0.99725	46.7	116	0.98600	71.7	161	0.97475
22.2	72	0.99700	47.2	117	0.98575	72.2	162	0.97450
22.8	73	0.99675	47.8	118	0.98550	72.8	163	0.97425
23.3	74	0.99650	48.3	119	0.98525	73.3	164	0.97400
23.9	75	0.99625	48.9	120	0.98500	73.9	165	0.97375
24.4	76	0.99600	49.4	121	0.98475	74.4	166	0.97350
25.0	77	0.99575	50.0	122	0.98450	75.0	167	0.97325
25.6	78	0.99550	50.6	123	0.98425	75.6	168	0.97300
26.1	79	0.99525	51.1	124	0.98400	76.1	169	0.97275
26.7	80	0.99500	51.7	125	0.98375	76.7	170	0.97250
27.2	81	0.99475	52.2	126	0.98350	77.2	171	0.97225
27.8	82	0.99450	52.8	127	0.98325	77.8	172	0.97200
28.3	83	0.99425	53.3	128	0.98300	78.3	173	0.97175
28.9	84	0.99400	53.9	129	0.98275	78.9	174	0.97150
29.4	85	0.99375	54.4	130	0.98250	79.4	175	0.97125
30.0	86	0.99350	55.0	131	0.98225	80.0	176	0.97100
30.6	87	0.99325	55.6	132	0.98200	80.6	177	0.97075
31.1	88	0.99300	56.1	133	0.98175	81.1	178	0.97050
31.7	89	0.99275	56.7	134	0.98150	81.7	179	0.97025
32.2	90	0.99250	57.2	135	0.98125	82.2	180	0.97000
32.8	91	0.99225	57.8	136	0.98100	82.8	181	0.96975
33.3	92	0.99200	58.3	137	0.98075	83.3	182	0.96950
33.9	93	0.99175	58.9	138	0.98050	83.9	183	0.96925
34.4	94	0.99150	59.4	139	0.98025	84.4	184	0.96900
						85.0	185	0.96875

Legend: t = observed temperature in degrees Celsius (Fahrenheit)
M = multiplier for correcting volumes to the basis of 15.6°C (60°F)

**Multiplier (M) for °C is a close approximation.*

TABLE G2 WEIGHT PER CUBIC FOOT AND PER CUBIC YARD OF DRY MINERAL AGGREGATES OF DIFFERENT SPECIFIC GRAVITY AND VARIOUS VOID CONTENTS

	Specific Gravity	VOIDS—PERCENT								
		15	20	25	30	35	40	45	50	55
POUNDS PER CUBIC FOOT	2.0	106.1	99.8	93.6	87.4	81.1	74.9	68.6	62.4	56.2
	2.1	111.4	104.8	98.3	91.7	85.2	78.6	72.1	65.5	59.0
	2.2	116.7	109.8	103.0	96.1	89.2	82.4	75.5	68.6	61.8
	2.3	122.0	114.8	107.6	100.5	93.3	86.1	78.9	71.8	64.6
	2.4	127.3	119.8	112.3	104.8	97.3	89.9	82.4	74.9	67.4
	2.5	132.6	124.8	117.0	109.2	101.4	93.6	85.8	78.0	70.2
	2.6	137.9	129.8	121.7	113.6	105.5	97.3	89.2	81.1	73.0
	2.7	143.2	134.8	126.4	117.9	109.5	101.1	92.7	84.2	75.8
	2.8	148.5	139.8	131.0	122.3	113.6	104.8	96.1	87.4	78.6
	2.9	153.8	144.8	135.7	126.7	117.6	108.6	99.5	90.5	81.4
	3.0	159.1	149.8	140.4	131.0	121.7	112.3	103.0	93.6	84.2
	3.1	164.4	154.8	145.1	135.4	125.7	116.1	106.4	96.7	87.0
	3.2	169.7	159.7	149.8	139.8	129.8	119.8	109.8	99.8	89.9
POUNDS PER CUBIC YARD	2.0	2860	2700	2530	2360	2190	2020	1850	1680	1520
	2.1	3010	2830	2650	2480	2300	2120	1950	1770	1590
	2.2	3150	2970	2780	2590	2410	2220	2040	1850	1670
	2.3	3290	3100	2910	2710	2520	2330	2130	1940	1740
	2.4	3440	3240	3030	2830	2630	2430	2220	2020	1820
	2.5	3580	3370	3160	2950	2740	2530	2320	2110	1900
	2.6	3720	3500	3290	3070	2850	2630	2410	2190	1970
	2.7	3870	3640	3410	3180	2960	2730	2500	2270	2050
	2.8	4010	3770	3540	3300	3070	2830	2590	2360	2120
	2.9	4150	3910	3660	3420	3180	2930	2690	2440	2200
	3.0	4300	4040	3790	3540	3290	3030	2780	2530	2270
	3.1	4440	4180	3920	3660	3400	3130	2870	2610	2350
	3.2	4580	4310	4040	3770	3500	3230	2970	2700	2430

1. *The Specific Gravity of commonly used road construction aggregates normally is within the following ranges:*

Granite	*2.6–2.9*	*Sandstone*	*2.0–2.7*
Gravel	*2.5–2.7*	*Traprock*	*2.7–3.2*
Limestone	*2.1–2.8*	*Blast Furnace Slag*	*2.0–2.5*
Sand (Quartzite)	*2.5–2.7*		

2. *Data contained in this table are applicable to dry mineral aggregates in either the loose or compacted state, and the void content should be selected accordingly. Preferably, both the void content and specific gravity should be determined in the laboratory.*

3. *The formulas for computation of data in table above are as follows:*

$$lb/ft^3 \qquad W = 62.4 \times \frac{G(100 - V)}{100} = 0.624G(100 - V)$$

and

$$lb/yd^3 \qquad W = 27 \times 62.4 \times \frac{G(100 - V)}{100} = 16.85G(100 - V)$$

Where: W = *Wt. per cu ft*
W = *Wt. per cu yd*
G = *Specific gravity*
V = *Air void content, percent*

TABLE G3 LINEAR MEASUREMENT COVERED BY TANK OF ANY CAPACITY FOR VARIOUS WIDTHS AND RATES OF APPLICATION

To compute the number of linear feet (metres) that will be covered by a tank of any capacity, for various widths and rates of application, use the applicable formula:

$$\text{U. S. Customary: } L = \frac{9C}{RW}$$

$$\text{S.I. Metric: } L = \frac{C}{RW}$$

where: L = No. of linear feet (metres) that will be covered
C = Capacity of tank in gallons (litres) (or quantity of asphalt in tank)
R = Rate of application in gallons per sq. yard (litres per sq. metre)
W = Width of application in feet (metres).

TABLE G4 LINEAR FEET COVERED BY 1000-GALLON TANK OF EMULSIFIED ASPHALT FOR VARIOUS WIDTHS AND RATES

Gals. per Sq. Yd.	WIDTH—FEET														
	1	2	6	7	8	9	10	11	12	14	16	18	20	22	24
0.10	90000	45000	15000	12857	11250	10000	9000	8182	7500	6429	5625	5000	4500	4091	3750
0.15	60000	30000	10000	8571	7500	6667	6000	5455	5000	4286	3750	3333	3000	2727	2500
0.20	45000	22500	7500	6429	5625	5000	4500	4091	3750	3214	2813	2500	2250	2045	1875
0.25	36000	18000	6000	5143	4500	4000	3600	3273	3000	2571	2250	2000	1800	1636	1500
0.30	30000	15000	5000	4286	3750	3333	3000	2727	2500	2143	1875	1667	1500	1363	1250
0.35	25714	12857	4286	3673	3214	2857	2571	2338	2143	1837	1607	1429	1286	1169	1071
0.40	22500	11250	3750	3214	2813	2500	2250	2045	1875	1607	1406	1250	1125	1022	937
0.45	20000	10000	3333	2857	2500	2222	2000	1818	1667	1429	1250	1111	1000	909	833
0.50	18000	9000	3000	2571	2250	2000	1800	1636	1500	1286	1125	1000	900	818	750
0.55	16364	8182	2727	2338	2046	1818	1636	1488	1364	1169	1023	909	818	744	682
0.60	15000	7500	2500	2143	1875	1667	1500	1364	1250	1071	938	833	750	682	625
0.65	13846	6923	2308	1978	1731	1538	1385	1259	1154	989	865	769	692	629	577
0.70	12857	6429	2143	1837	1607	1429	1286	1169	1071	918	804	714	643	584	535
0.75	12000	6000	2000	1714	1500	1333	1200	1091	1000	857	750	667	600	545	500
0.80	11250	5625	1875	1607	1406	1250	1125	1023	938	804	703	625	563	511	469
0.85	10588	5294	1765	1513	1324	1176	1059	963	882	756	662	588	529	481	441
0.90	10000	5000	1667	1429	1250	1111	1000	909	833	714	625	556	500	454	416
0.95	9474	4737	1579	1353	1184	1053	947	861	789	676	592	526	473	430	394
1.00	9000	4500	1500	1286	1125	1000	900	818	750	643	563	500	450	409	375
1.10	8182	4091	1364	1169	1023	909	818	744	682	584	511	454	409	372	341
1.20	7500	3750	1250	1071	938	833	750	682	625	535	469	416	375	341	312
1.25	7200	3600	1200	1029	900	800	720	655	600	514	450	400	360	327	300
1.30	6923	3462	1154	989	866	769	692	629	577	494	433	384	346	314	288
1.40	6429	3215	1072	918	804	714	643	584	536	459	402	357	321	292	268
1.50	6000	3000	1000	857	750	667	600	545	500	429	375	333	300	272	250
1.75	5143	2571	857	735	643	571	514	468	429	367	321	286	257	234	214
2.00	4500	2250	750	643	563	500	450	409	375	321	281	250	225	204	187
2.25	4000	2000	667	571	500	444	400	364	333	286	250	222	200	182	166
2.50	3600	1800	600	514	450	400	360	327	300	257	225	200	180	163	150
2.75	3273	1636	545	468	409	364	327	298	272	234	204	182	163	149	136
3.00	3000	1500	500	429	375	333	300	273	250	214	187	167	150	136	125

Note: See Table V for formula used for calculation. For metric conversion factors refer to Table II .

TABLE G5 GALLONS OF EMULSIFIED ASPHALT REQUIRED PER 100 LINEAR FEET: VARIOUS WIDTHS AND RATES

Gals. per Sq. Yd.	WIDTH—FEET														
	1	2	6	7	8	9	10	11	12	14	16	18	20	22	24
0.10	1.1	2.2	6.7	7.8	8.9	10.0	11.1	12.2	13.3	15.6	17.8	20.0	22.2	24.4	26.7
0.15	1.7	3.3	10.0	11.7	13.3	15.0	16.7	18.3	20.0	23.3	26.7	30.0	33.3	36.7	40.0
0.20	2.2	4.4	13.3	15.6	17.8	20.0	22.2	24.4	26.7	31.1	35.6	40.0	44.4	48.9	53.3
0.25	2.8	5.6	16.7	19.4	22.2	25.0	27.8	30.6	33.3	38.9	44.4	50.0	55.6	61.1	66.7
0.30	3.3	6.7	20.0	23.3	26.7	30.0	33.3	36.7	40.0	46.7	53.3	60.0	66.7	73.3	80.0
0.35	3.9	7.8	23.3	27.2	31.1	35.0	38.9	42.8	46.7	54.4	62.2	70.0	77.8	85.5	93.3
0.40	4.4	8.9	26.7	31.1	35.6	40.0	44.4	48.9	53.3	62.2	71.1	80.0	88.9	97.8	107.
0.45	5.0	10.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	70.0	80.0	90.0	100.	110.	120.
0.50	5.6	11.1	33.3	38.9	44.4	50.0	55.5	61.1	66.7	77.8	88.9	100.	111.	122.	133.
0.55	6.1	12.2	36.7	42.8	48.9	55.0	61.1	67.2	73.3	85.5	97.8	110.	122.	134.	147.
0.60	6.7	13.3	40.0	46.7	53.3	60.0	66.7	73.3	80.0	93.3	107.	120.	133.	147.	160.
0.65	7.2	14.4	43.3	50.6	57.8	65.0	72.2	79.4	86.7	101.	115.	130.	144.	159.	173.
0.70	7.8	15.6	46.7	54.4	62.2	70.0	77.8	85.5	93.3	109.	124.	140.	156.	171.	187.
0.75	8.3	16.7	50.0	58.3	66.7	75.0	83.3	91.7	100.	117.	133.	150.	167.	183.	200.
0.80	8.9	17.8	53.3	62.2	71.1	80.0	88.9	97.8	107.	124.	142.	160.	178.	196.	213.
0.85	9.4	18.9	56.7	66.1	75.5	85.0	94.4	104.	113.	132.	151.	170.	189.	208.	227.
0.90	10.0	20.0	60.0	70.0	80.0	90.0	100.	110.	120.	140.	160.	180.	200.	220.	240.
0.95	10.6	21.1	63.3	73.9	84.4	95.0	106.	116.	127.	148.	169.	190.	211.	232.	253.
1.00	11.1	22.2	66.7	77.8	88.9	100.	111.	122.	133.	156.	178.	200.	222.	244.	267.
1.10	12.2	24.4	73.3	85.5	97.8	110.	122.	134.	147.	171.	196.	220.	244.	269.	293.
1.20	13.3	26.7	80.0	93.3	107.	120.	133.	147.	160.	187.	213.	240.	267.	293.	320.
1.25	13.9	27.8	83.3	97.2	111.	125.	139.	153.	167.	194.	222.	250.	278.	306.	333.
1.30	14.4	28.9	86.7	101.	116.	130.	144.	159.	173.	202.	230.	260.	288.	318.	347.
1.40	15.6	31.1	93.3	109.	124.	140.	156.	171.	187.	218.	249.	280.	311.	342.	373.
1.50	16.7	33.3	100.	117.	133.	150.	167.	183.	200.	233.	267.	300.	333.	367.	400.
1.75	19.4	38.9	117.	136.	156.	175.	194.	214.	233.	272.	311.	350.	389.	427.	467.
2.00	22.2	44.4	133.	156.	178.	200.	222.	244.	267.	311.	356.	400.	444.	489.	533.
2.25	25.0	50.0	150.	175.	200.	225.	250.	275.	300.	350.	400.	450.	500.	550.	600.
2.50	27.8	55.6	167.	194.	222.	250.	278.	306.	333.	389.	444.	500.	556.	611.	667.
2.75	30.6	61.1	183.	214.	244.	275.	306.	336.	367.	428.	489.	550.	611.	672.	733.
3.00	33.3	66.7	200.	233.	267.	300.	333.	367.	400.	467.	533.	600.	667.	733.	800.

Note: *Formula used for calculation:* $Q = \frac{100W}{9} R = 11.11WR$

Where: *Q = Quantity of asphalt required, in gallons per 100 ft. (l/m)*
R = Rate of application in gallons per sq. yd. (l/m^2)
W = Width of application, in feet (m)

For metric conversion factors see Table G9 *. Metric formula for calculation: Q = LWR where L = length in metres.*

TABLE G6 TONS OF AGGREGATE REQUIRED PER MILE FOR VARIOUS WIDTHS AND RATES

Spread Rate	Spread Width (in Feet)						
	8	9	10	12	16	18	20
lb/yd^2	Tons Per Mile	Tons Per Mile	Tons Per Mile	Tons Per Mile	Tons Per Mile	Tons Per Mile	Tons Per Mile
5	12	13	15	18	23	26	29
10	23	26	29	35	47	53	59
15	35	40	44	53	70	79	88
20	47	53	59	70	94	106	117
25	59	66	73	88	117	132	147
30	70	79	88	106	141	158	176
35	82	92	103	123	164	185	205
40	94	106	117	141	188	211	235
45	106	119	132	158	211	238	264
50	117	132	147	176	235	264	293
60	141	158	176	211	282	317	352
75	176	198	220	264	352	396	440
100	235	264	293	352	469	528	587
150	352	396	440	528	704	792	880
200	469	528	587	704	939	1056	1173
250	587	660	733	880	1173	1320	1467
300	704	792	880	1056	1408	1584	1760

To convert from	*to*	*Multiply by*
Feet	*metres*	*0.3048*
lb/yd^2	*kg/m^2*	*0.542492*
tons/mi	*Mg/km*	*0.563698*

TABLE G7 QUANTITIES AT DEPTHS IN CYLINDRICAL TANKS IN A HORIZONTAL POSITION

Percent Depth Filled	Percent of Capacity	Percent Depth Filled	Percent of Capacity	Percent Depth Filled	Percent of Capacity	Percent Depth Filled	Percent of Capacity
1	0.20	26	20.73	51	51.27	76	81.50
2	0.50	27	21.86	52	52.55	77	82.60
3	0.90	28	23.00	53	53.81	78	83.68
4	1.34	29	24.07	54	55.08	79	84.74
5	1.87	30	25.31	55	56.34	80	85.77
6	2.45	31	26.48	56	57.60	81	86.77
7	3.07	32	27.66	57	58.86	82	87.76
8	3.74	33	28.84	58	60.11	83	88.73
9	4.45	34	30.03	59	61.36	84	89.68
10	5.20	35	31.19	60	62.61	85	90.60
11	5.98	36	32.44	61	63.86	86	91.50
12	6.80	37	33.66	62	65.10	87	92.36
13	7.64	38	34.90	63	66.34	88	93.20
14	8.50	39	36.14	64	67.56	89	94.02
15	9.40	40	37.39	65	68.81	90	94.80
16	10.32	41	38.64	66	69.97	91	95.55
17	11.27	42	39.89	67	71.16	92	96.26
18	12.24	43	41.14	68	72.34	93	96.93
19	13.23	44	42.40	69	73.52	94	97.55
20	14.23	45	43.66	70	74.69	95	98.13
21	15.26	46	44.92	71	75.93	96	98.66
22	16.32	47	46.19	72	77.00	97	99.10
23	17.40	48	47.45	73	78.14	98	99.50
24	18.50	49	48.73	74	79.27	99	99.80
25	19.61	50	50.00	75	80.39		

Full capacity of tank in U.S. gallons = $\frac{0.7854 \times D^2 \times L}{231}$

D = Diameter of tank in inches
L = Length of tank in inches

Full capacity of tank in litres = $\frac{\pi \times D^2 \times L}{4000}$

D = Diameter of tank in centimetres
L = Length of tank in centimetres

Note: The calculated tank volume should be corrected for any internals such as piping, fitting, etc. Also, the tank should be level horizontally.

TABLE G8 AREAS PER MILE AND PER 1000 LINEAR FEET FOR VARIOUS WIDTHS

Width in Feet	Square Feet Per Mile	Square Yards Per Mile	Square Yards Per 1000 Lin. Ft.
1	5,280	587	111.1
2	10,560	1,173	222.2
3	15,840	1,760	333.3
4	21,120	2,347	444.4
5	26,400	2,933	555.6
6	31,680	3,520	666.7
7	36,960	4,107	777.8
8	42,240	4,693	888.9
9	47,520	5,280	1,000.0
10	52,800	5,867	1,111.1
12	63,360	7,040	1,333.3
14	73,920	8,213	1,555.6
15	79,200	8,800	1,666.7
16	84,480	9,387	1,777.8
18	95,040	10,560	2,000.0
20	105,600	11,733	2,222.2
22	116,160	12,907	2,444.4
24	126,720	14,080	2,666.7
26	137,280	15,253	2,888.9
28	147,840	16,427	3,111.1
30	158,400	17,600	3,333.3
32	168,960	18,773	3,555.6
36	190,080	21,120	4,000.0
40	211,200	23,467	4,444.4
50	264,000	29,333	5,555.6
60	316,800	35,200	6,666.7

To convert from	*to*	*Multiply by*
feet	*metres*	*0.3048*
ft^2/mi	*m^2/km*	*0.189394*
yd^2/mi	*m^2/km*	*0.337089*
$yd^2/1{,}000\ ft$	*$m^2/300m$*	*0.009144*

TABLE G9 CONVERSION FACTORS: U.S. CUSTOMARY TO METRIC UNITS

To convert from	To	Multiply by
acre	metre^2 (m^2)	4 046.856
acre	hectometre^2 (hm^2)	0.404 686
Atmosphere (technical = 1kgf/cm^2)	kilopascal (kPa)	98.066 50
barrel (42 gal.)	decimetre^3 (dm^3) or litre (l)	158.987 3
BTU (International Table)	kilojoule (kJ)	1.055 056
bushel	decimetre^3 (dm^3)	35.239 1
dyne	micronewton (μN)	10.000 0
dyne/centimetre^2	pascal (Pa)	0.100 0
Fahrenheit (temperature)	Celsius (°C)	$t_c = (t_f-32)/1.8$
foot	metre (m)	0.304 80
foot^2	metre^2 (m^2)	0.092 903
foot^3	metre^3 (m^3)	0.028 317
	litre (l)	28.317 0
foot-pound-force	joule (J)	1.355 818
foot/minute	metre/second (m/s)	0.005 08
foot/second^2	metre/second^2 (m/s^2)	0.304 80
gallon (U.S. liquid)	decimetre^3 (dm^3) or litre (l)	3.785 412
	metre^3 (m^3)	0.003 785
gallon/minute	decimetre^3/second (dm^3/s) or litre/second (l/s)	0.063 09
gallon/yard^2	decimetre^3/metre^2 (dm^3/m^2) or litre/metre^2 (l/m^2)	4.527 314
horsepower (electric)	kilowatt (kW)	0.746 0
inch	millimetre (mm)	25.400 0
inch^2	centimetre^2 (cm^2)	6.451 60
inch^2	millimetre^2 (mm^2)	645.160 0
inch^3	centimetre^3 (cm^3)	16.387 06
inch/second	metre/second (m/s)	0.025 40
inch of mercury (60°F)	pascal (Pa)	3 376.85
inch/second^2	metre/second^2 (m/s^2)	0.025 40
kilogram (kg)	ton (metric)	0.001 00
kip (1 000 lbf)	kilonewton (kN)	4.448 222
kip/inch^2	megapascal (MPa)	6.894 757
mile (U.S. statute)	kilometre (km)	1.609 344
mile^2	kilometre^2 (km^2)	2.589 988
mile/hour	kilometre/hour (km/hr)	1.609 344
minute (angle)	radian (rad)	0.000 290 89
ounce-force	newton (N)	0.278 013 9
ounce-mass	gram (g)	28.349 52
ounce-fluid	centimetre^3 (cm^3)	29.573 53
	litre (l)	0.029 574
pint (U.S. liquid)	litre (l)	0.473 176 5
poise (absolute viscosity)	pascal-second (Pa·s)	0.100 000
pound-force (lbf)	newton (N)	4.448 222
	kilonewton (kN)	0.004 448
pound-force-inch	newton-metre (N.m)	0.112 984 8
pound-force/foot^2	pascal (Pa)	47.880 26
pound-force/inch^2 (psi)	kilopascal (kPa)	6.894 757
pound-mass	kilogram (kg)	0.453 592 4
pound-mass/foot^2	kilogram/metre^2 (kg/m^2)	4.882 428
pound-mass/foot^3	kilogram/metre^3 (kg/m^3)	16.018 46
	megagram/metre^3 (Mg/m^3)	0.016 018
pound-mass/inch^3	kilogram/decimetre^3 (kg/dm^3)	27.679 90
pound-mass/yard^2	kilogram/metre^2 (kg/m^2)	0.542 492
pound-mass/yard^3	kilogram/metre^3 (kg/m^3)	0.593 276
pound-mass/gallon (U.S. liquid)	kilogram/metre^3 (kg/m^3)	119.826 4
	kilogram/decimetre^3 (kg/dm^3)	0.119 826
psi	kilopascal (kPa)	6.894 757
quart (U.S. liquid)	decimetre^3 (dm^3) or litre (l)	0.946 352 9
ton (metric)	kilogram (kg)	1 000.000 0
ton (short-2 000 lb)	kilogram (kg)	907.184 7
ton (long-2 240 lb)	kilogram (kg)	1 016.046 1
ton-mass/yard^3	kilogram/metre^3 (kg/m^3)	1 186.552 7
yard	metre (m)	0.914 40
yard^2	metre^2 (m^2)	0.836 127 4
yard^3	metre^3 (m^3)	0.764 554 9

TABLE G10

Cost of Asphalt Binders Per Square Yard – Various Rates and Prices Per Gallon

Courtesy: Chevron U.S.A.

Rates of Application Gallons per Sq. Yd.		PRICE PER GALLON (United States Currency - Cents)									
		.50	.55	.60	.65	.70	.75	.80	.85	.90	.95
1/10	.10	.05	.055	.060	.065	.07	.075	.080	.085	.09	.095
1/8	.125	.0625	.0688	.075	.081	.088	.094	.10	.106	.113	.119
1/6	.167	.0835	.0919	.100	.109	.117	.125	.134	.142	.150	.159
1/5	.20	.10	.11	.12	.13	.14	.15	.16	.17	.18	.19
1/4	.25	.125	.138	.15	.163	.175	.188	.20	.213	.225	.238
3/10	.30	.150	.165	.18	.195	.21	.225	.24	.255	.27	.285
1/3	.333	.167	.183	.20	.216	.233	.250	.266	.283	.210	.316
3/8	.375	.188	.206	.225	.244	.263	.281	.30	.319	.338	.356
2/5	.40	.20	.22	.24	.26	.28	.30	.32	.34	.36	.38
1/2	.50	.25	.275	.30	.325	.35	.375	.40	.425	.45	.475
3/5	.60	.30	.33	.36	.39	.42	.45	.48	.51	.54	.57
5/8	.625	.313	.344	.375	.406	.438	.469	.50	.531	.563	.594
2/3	.667	.334	.367	.40	.434	.467	.50	.534	.567	.60	.634
3/4	.75	.375	.413	.45	.488	.525	.563	.60	.638	.675	.713
7/8	.875	.438	.481	.525	.569	.613	.656	.70	.744	.788	.831
1	1.0	.50	.55	.60	.65	.70	.75	.80	.85	.90	.95
1-1/4	1.25	.625	.688	.75	.813	.88	.938	1.0	1.063	1.125	1.188
1-1/2	1.50	.75	.825	.90	.975	1.05	1.13	1.20	1.275	1.35	1.43
1-3/4	1.75	.875	.963	1.05	1.14	1.23	1.31	1.40	1.49	1.58	1.66
2	2.00	1.00	1.10	1.20	1.30	1.40	1.50	1.60	1.70	1.80	1.90